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Satoshi KUROYANAGI, et al.

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APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents.

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1. [X] Fee Transmittal Form
2. [X] Specification, Claims & Abstract ..... [Total Pages: 39]
3. [X] Drawing(s) *(35 USC 113)* .... [Total Sheets: 22]
4. [X] Oath or Declaration .... [Total Pages: 3]
   a. [X] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 17 completed)*
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      Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
5. [ ] Incorporation by Reference (usable if Box 4b is checked)
   The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
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8. [X] Assignment Papers (cover sheet & document(s))
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18. CORRESPONDENCE ADDRESS

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Docket No. 1046.1206/JDH

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Satoshi KUROYANAGI, et al.

Serial No.: To Be Assigned

Filed: December 21, 1999

For: OPTICAL PATH CROSSCONNECT SYSTEM WITH HIGH EXPANDING CHARACTERISTIC

Group Art Unit: To Be Assigned

Examiner: To Be Assigned

PRELIMINARY AMENDMENT

Assistant Commissioner of Patents
and Trademarks
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Dear Sir:

Prior to the examination of the above-identified application, please AMEND the application as follows:

IN THE CLAIMS:

Please AMEND the claims as follows:

Claim 9, line 2, change "any one of the preceding claims 5 to 8" to --claim 3--.

Claim 10, line 3, change "any one of the preceding claims 1 to 4" to --claim 1--.

REMARKS

This Preliminary Amendment is submitted to improve the form of the specification as originally filed.

It is respectfully requested that this Preliminary Amendment be entered in the above-references application.

If any fees are required in connection with the filing of this Preliminary Amendment, please charge same to our Deposit Account No. 19-3935.

Respectfully submitted,

STAAS & HALSEY

Date: December 21, 1999

By: ______________________________

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OPTICAL PATH CROSSCONNECT SYSTEM WITH HIGH EXPANDING CHARACTERISTIC

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an effective technique applied to an arrangement of an optical path cross-connect system used to construct a large-scaled optical network in correspondence with an increase in a total number of wavelengths.

2. Description of the Related Art

Very recently, while large amounts of information are communicated in high speeds, very broad band networks as well as very wide range transfer systems with large capacities are required. As one of means capable of realizing such needs, a WDM-technique based optical network is desirably constructed. A core device required when such an optical network is constructed corresponds to an optical path cross-connect (optical XC).

Fig. 1 illustratively shows a typical structural example of an optical XC system and an optical network. As indicated in this drawing, the optical path cross-connect (XC) device is such a device which contains a plurality of input/output optical transmission lines, and

routes wavelength-division multiplexed optical signals which are entered from the input optical transmission line into a desirable output optical transmission line wavelength-by-wavelength When a long distance transmission line is constructed, an optical amplifier is inserted to the optical transmission lines between the optical XC device, and the optical XC device is connected to another communication device (for example, electric cross connect: electric XC) through the intra-office optical transmission lines. Then, these devices are controlled by an operation system for managing the entire network.

On the other hand, a total number of wavelengths is rapidly increased in an optical network in connection with an increase of traffic capacity. However, when a total number of wavelengths is increased, a system scale required for the optical XC device is increased, which may cause a practical difficulty.

In the optical XC system, there are two different types, i.e., a wavelength fixing type XC system in which a wavelength is not converted within a node; and a wavelength converting type XC system in which a wavelength is converted within a node, if required. Fig. 2(a) and Fig. 2(b) represent general structures of the respective

wavelength fixing/converting type XC systems with employment of optical switches. The wavelength fixing type XC system indicated in Fig. 2(b) is constituted by a wavelength-division demultiplexer, an optical switch unit, and a wavelength-division multiplexer. Since the optical switch is controlled in this wavelength fixing type XC system, an input optical signal is routed to a desirable output transmission line while keeping the wavelength thereof unconverted.

On the other hand, the wavelength converting type XC system indicated in Fig. 2(a) requires a wavelength converter used to convert the wavelength (note that output wavelength is fixed), as compared with the above-explained wavelength fixing type XC system, and also controls the optical switch in order to convert the wavelength of this input optical signal into a desirable wavelength of a desirable output transmission line.

It should be understood that as an example of the wavelength converter, there are provided two different converting systems, namely a wavelength of an input optical signal is directly converted into a desirable wavelength while maintaining the optical signal form by utilizing an optical semiconductor element, and a wavelength of an input optical signal is converted into a desirable wavelength

by using both an optical/electric converter and an electric/optical converter. Also, as an example of the optical switch, there are provided a dielectric element such as LiNbO3, an optical semiconductor element such as InP and GaAs, a sillica-based waveguide switch realized by utilizing the thermo-optic effect, and a mechanical optical switch realized by utilizing a stepper motor and a prism. Furthermore, as an example of the wavelength-division demultiplexer and the wavelength-division multiplexer, such elements may be employed which use an array waveguide grating and a dielectric multilayer film.

Fig. 3 is a conceptional view indicating an optical path network in such an optical network established when the conventional optical XC device indicated in Fig. 2 is employed.

As shown in Fig. 3(a), in the wavelength converting type optical path network, a wavelength is allocated in a link-by-link basis between a sender and a receiver node with respect to a single optical path. In other words, a wavelength is converted with respect to each of repeating optical XC device, if required.

On the other hand, as shown in Fig. 3(b), in the wavelength fixing type optical path network, a single wavelength is allocated between a sender and a receiver

node with respect to a single optical path. In other words, the wavelength is not converted within a repeating optical XC device.

In this case, the below-mentioned problems occur, comparing the wavelength fixing type optical path network with the wavelength converting type optical path network.

That is, in the wavelength fixing type optical path network, when the optical signal having the same wavelength as that of the wavelength-multiplexed optical signal which is entered from the input optical transmission line is routed to the same output optical transmission line, blocking will occur.

On the other hand, since the wavelengths can be converted in the wavelength converting type optical path network if necessary, even when the optical signals having the same wavelengths are routed to the same output transmission line, the optical signal can be routed without any occurrence of such blocking. However, a large-scaled optical switch is required, as compared with that of the wavelength fixing type optical path network. Furthermore, in the wavelength converting type optical path network, when a total number of wavelengths is increased, the scale of the optical switch must be enlarged (namely, this optical switch must be replaced by another large-scaled

optical switch). As a consequence, the wavelength converting type optical path network is not superior in the expanding characteristic with respect to a total number of wavelengths. To the contrary, in the wavelength fixing type optical path network, a total number of optical switches may be increased, depending upon an increase of wavelength number.

In summary, there are the following problems that the transfer characteristic (blocking characteristic) is deteriorated in the wavelength fixing type optical path network, whereas the wavelength converting type optical path network has no expanding characteristic with respect to increasing of the wavelength number, and the scale of the entire device is enlarged.

The present invention has been made in view of such problems, and therefore, has an object to realize an optical path cross connect technique with a high expanding characteristic with respect to an increase in a total number of wavelengths, while maintaining a better transfer characteristic.

SUMMARY OF THE INVENTION

To achieve the above-described object, according to a first means of the present invention, there is provided

an optical XC device in which an Optical transmission line (inter-office) allows a multiplexed wavelength and an optical transmission line (intra-office) employs a non-multiplexed wavelength, a wavelength separating means is provided every transmission line (inter-office), and also, an intra-office signal input means is provided so as to demultiplex a wavelength-multiplexed optical signal entered from the transmission line (inter-office) to a first optical path group, and repeat a wavelength-non-multiplexed signal to the first optical path group. Then, this optical XC device is provided with "m" pieces of routing means for inputting thereinto an optical signal via this first optical path group, and for converting this optical input signal into a predetermined wavelength to thereby output the wavelength-converted optical signal to a second optical path group. The "m" (symbol "m" being an integer and also being larger than 1)" pieces of routing means are subdivided in a unit of at least "n" (symbol "n" being an integer and also being larger than 1)" wavelengths.

Furthermore, there are provided a wavelength combining means for selectively wavelength-multiplexing the optical signal through the second optical path group, and an intra-office signal output means for selectively

repeating the optical signal at a post stage of the above-explained routing means.

It should be noted that in the first means, the intra-office signal input means can be constituted by an optical space switch, the routing means can be arranged by an optical space switch and a wavelength converter, and the intra-office signal output means can be arranged by an optical space switch.

Also, a regenerator constructed of both an opto-electric converter and an electric-optical converter may be inserted at any one of an input of the optical space switch or an output thereof.

Also, a plurality of the optical path cross-connect devices according to the first means may be employed so as to construct an optical network.

As previously explained in detail, a single sub-network is constituted by the wavelength converting type routing means in the unit of extension. Then, the wavelength converting type routing means are successively added in response to an increase in the wavelength numbers (namely, a plurality of sub-networks are additionally provided) so as to constitute a large-scaled optical XC device and an optical network. In this case, the wavelength ranges to be processed by the respective routing

means are made different from each other.

As a consequence, while maintaining the transfer characteristic, the present invention is provided with the expanding characteristic with respect to the wavelength number. Furthermore, it can prevent the large-scaled system. This may contribute to an improvement in the performance of the optical transfer system with employment of this arrangement.

According to a second means of the present invention, in the above-explained first means, the optical signal transferred to the transmission line (intra-office) is wavelength-multiplexed, and both the intra-office signal input means and the intra-office signal output means repeat the wavelength-multiplexed optical signal.

It should also be noted that the intra-office signal input means can be arranged by a wavelength-division demultiplexer, and an optical space switch; the routing means can be constituted by an optical space switch and a wavelength converter; and the inter-office signal output means can be arranged by an optical space switch, a wavelength converter, and a wavelength-division multiplexer.

According to a third means of the present invention, there is provided an optical XC device in which an optical

transmission line (inter-office) allows a multiplexed wavelength and an intra-office transmission line employs a non-mulitplexed wavelength, an optical branching means is provided with each of the optical transmission line (inter-office), for branching a wavelength-multiplexed optical signal into "m (symbol "m" being an integer and also being larger than 1)" pieces of first optical path groups, while maintaining the wavelength-multiplexed state; and an intra-office signal input means is provided with each of the intra-office transmission line for repeating a wavelength-non-multiplexed optical signal entered from this intra-office transmission line.

Furthermore, the third means is provided with "m" pieces of routing means for routing an optical signal within a pre-allocated wavelength range from optical signals outputted from the optical branching means and the intra-office signal input means to an inter-office signal output unit, and for converting the optical signal within the pre-allocated wavelength range into a desirable wavelength to route the wavelength-converted optical signal to a second optical path group, and the "m (symbol "m" being an integer and also being larger than 1)" pieces of routing means are subdivided in a unit of at least "n (symbol "n" being an integer and also being larger than

1)" wavelengths. Furthermore, there are provided a wavelength combining means for selectively wavelength-multiplexing the optical signal, and an intra-office signal output means for selectively repeating the optical signal at a post stage of the above-explained routing means.

It should also be noted that the intra-office signal input means can be constituted by an optical space switch; the routing means can be arranged by a wavelength-division demultiplexer, an optical space switch, a wavelength converter and a wavelength-division multiplexer; and the intra-office signal output means can be arranged by an optical space switch.

According to a fourth means of the present invention, in the above-explained third means, the optical signal transferred to the optical transmission line (intra-office) is wavelength-multiplexed, and both the intra-office signal input means and the intra-office signal output means repeat the wavelength-multiplexed optical signal.

It should be understood that the intra-office signal input means can be constituted by a wavelength-division demultiplexer and an optical space switch; the routing means can be arranged by a wavelength-division

demultiplexer, an optical space switch, a wavelength converter and a wavelength-division multiplexer; and the inter-office signal output means can be arranged by an optical space switch, a wavelength converter and a wavelength-division multiplexer.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention, reference is made of a detailed description to be read in conjunction with the accompanying drawings, in which:

Fig. 1 is a diagram illustratively showing a typical optical path cross-connect device system and a typical optical network;

Fig. 2 is a node structural diagram of a typically conventional optical XC device;

Fig. 3 shows an optical path network diagram in the case that the conventional optical XC device is employed;

Fig. 4 illustratively shows a basic structural diagram of an optical XC device according to an embodiment 1 of the present invention;

Fig. 5 illustratively shows a basic structural diagram of an optical XC device according to an embodiment 2 of the present invention;

Fig. 6 illustratively shows a basic structural

diagram of an optical XC device according to an embodiment 3 of the present invention;

Fig. 7 illustratively shows a basic structural diagram of an optical XC device according to an embodiment 4 of the present invention;

Fig. 8 is a concrete structural diagram explaining the routing operation by the optical XC device of the embodiment 1;

Fig. 9 is a concrete structural diagram explaining the routing operation by the optical XC device of the embodiment 2;

Fig. 10 is a concrete structural diagram explaining the routing operation by the optical XC device of the embodiment 3;

Fig. 11 is a concrete structural diagram explaining the routing operation by the optical XC device of the embodiment 4;

Fig. 12 illustratively represents structural drawings of the respective units employed in the optical XC device of the embodiment 1;

Fig. 13 illustratively represents structural drawings of the respective units employed in the optical XC device of the embodiment 2;

Fig. 14 illustratively represents structural

drawings of the respective units employed in the optical XC device of the embodiment 3;

Fig. 15 illustratively represents structural drawings of the respective units employed in the optical XC device of the embodiment 4;

Fig. 16 is an explanatory diagram explaining the optical path network of the embodiment 1;

Fig. 17 is an explanatory diagram explaining the monitor/control system of the embodiment 1;

Fig. 18 is an explanatory diagram explaining the routing operation of the optical XC device of the embodiment 1;

Fig. 19 is an explanatory diagram (1) for explaining the switching operation of an optical switch according to the embodiment 1;

Fig. 20 is an explanatory diagram (2) for explaining the switching operation of the optical switch according to the embodiment 1;

Fig. 21 is an explanatory diagram (3) for explaining the switching operation of the optical switch according to the embodiment 1; and

Fig. 22 is a structural diagram of an optical space switch employed in the embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to drawings, various preferred embodiments of the present invention will be described in detail.

ARRANGEMENT OF FIRST OPTICAL XC DEVICE

Fig. 4 illustratively indicates an arrangement of an optical XC device according to an embodiment 1 of the present invention. Also, Fig. 8 represents a concrete routing operation of this first optical XC device.

In this drawing, a wavelength branching unit is provided every optical transmission line between input offices. An optical signal having a multiplexed wavelength defined from "$\lambda 11$" to "λmn" is inputted into this wavelength branching unit. This wavelength branching unit demultiplexes the above-described multiplexed wavelength to distribute the separated wavelengths to the respective optical path groups ($\lambda 11$ to $\lambda 1n$), ($\lambda 21$ to $\lambda 2n$),---, ($\lambda m1$ to λmn). Then, this wavelength branching unit inputs these separated optical signals of the optical path groups into routing units.

The routing unit constituted by "m" pieces of routing units is subdivided in a unit of "n" wavelengths, and the subdivided routing units perform routing process operations. This routing unit is arranged by an optical

space switch and a wavelength converter.

An intra-office signal input unit has the following functions. That is, non-multiplexed wavelength signals supplied from an optical transmission line between input offices are repeated and then distributed to "m" pieces of routing units.

Fig. 8 represents a detailed explanatory diagram of these functions. As indicated in this drawing, in this embodiment 1, a total number of wavelengths appearing on the input side is selected to be 32, these 32 wavelengths are distributed into 4 sets of routing units in a unit of 8 wavelengths. Also, a ratio of optical signal channel number derived from an optical transmission line (inter-office) to optical signal channel number derived from an intra-office transmission line is selected to be 3:1. As a result, a total channel number of the optical signals (inter-office) is equal to $32 \times 6 = 192$, and a total channel number of the intra-office optical signals is equal to $32 \times 2 = 64$.

It should be noted that this intra-office signal input unit may be constructed by an optical space switch.

Fig. 22 indicates a structural example of an optical space switch (4×4). Similarly, as apparent from this structural example, the hardware scale of this optical

space switch is increased in accordance with a product of quantities of input/output ports. For instance, in the case of 4×4, 16 sets of 2×2 optical switches are required.

Fig. 12 indicates an arrangement of this intra-office signal input unit, an arrangement of the routing unit, and an arrangement of the intra-office signal output unit. The intra-office signal input unit is constituted by 64×64 optical switches. The routing unit is arranged by 64×64 optical switches and wavelength converters. In the wavelength converters, the output wavelengths of the optical signals sent out to the optical transmission line between the output offices correspond to the wavelengths allocated to the respective routing units, and all of the output wavelength of the optical signals sent out to the intra-office optical transmission line are equal to each other. The intra-office signal output unit is constituted by 64 64 optical switches.

Fig. 16 is a conceptional diagram of an optical path network in an optical network established when the optical XC device according to the embodiment 1 of the present invention is employed. As indicated in this drawing, the optical path network is constituted by 4 sets of wavelength converting type sub-networks #1 ($\lambda 1$ to $\lambda 8$) to #4 ($\lambda 25$ to $\lambda 32$) in a unit of 8 wavelengths in this embodiment. With

respect to a single optical path, a single sub-network is selected between a sender and a receiver node, and the wavelengths are allocated within this sub-network in a link-by-link basis.

Fig. 17 shows an arrangement of a network equipped with a monitor/control system based on the optical XC device shown in Fig. 4 according to the present invention.

As shown in Fig. 17, the monitor/control system according to this embodiment is arranged by a monitor circuit, a drive circuit for driving an intra-office signal input unit, another drive circuit for driving a routing unit, another drive circuit for driving an intra-office signal output unit, and a further monitor circuit. The first-mentioned monitor circuit monitors both an optical transmission line between input offices and an intra-input office optical transmission line. The last-mentioned monitor circuit monitors both an optical transmission line output office and an intra-office transmission line.

Then, these monitor circuits and drive circuits are controlled by a control circuit.

In this drawing, upon receipt of path setting signals (for example, input optical link number, input wavelength value, output optical link number, output wavelength value) entered from an operation system, the control

circuit analyzes control points of optical switches of the intra-office signal input unit, the routing unit, and the intra-office signal output unit based on the path setting signals.

Then, the control circuit sends out a control signal to a drive circuit of an optical switch, and this drive circuit produces a drive signal based on this control signal to send out the produced drive signal.

Also, in the input/output links of the optical XC device, the monitor circuits monitor both characteristics and path connections as to both an input wavelength-multiplexed optical signal and an output wavelength-multiplexed optical signal. Then, the monitor circuits continuously notify the monitoring results to the control circuit. When the control circuit judges an occurrence of an abnormal state, this control circuit notifies this abnormal state to the operation system.

OPERATIONS OF FIRST OPTICAL XC DEVICE

Fig. 18 is an explanatory diagram for explaining an operation example of the optical XC device according to the embodiment 1. Also, Fig. 19 to Fig. 21 represent operation examples of the respective units based on the operation example of Fig. 18.

First, as shown in Fig. 19(a), an optical signal A

($\lambda 0$) entered from the intra-input office optical transmission line #64 is entered via the first optical line ($\lambda 0$) to the routing unit ($\lambda 9$ to $\lambda 16$) in the intra-office signal input unit (see Fig. 20(b)), and is further converted into an optical signal having a wavelength of "$\lambda 16$" by the wavelength converter. The optical signal having the wavelength of $\lambda 16$ is routed via a wavelength combining unit to the optical transmission line between output office.

Also, another optical signal B ($\lambda 25$) supplied from the optical transmission line between input offices #6 is inputted via the first optical line ($\lambda 25$ to $\lambda 32$) separated from the wavelength branching unit into the routing unit for $\lambda 25$ to $\lambda 32$ (see Fig. 21(b)). The wavelength $\lambda 25$ of this optical signal B is converted into the wavelength $\lambda 0$ by the wavelength converter of this routing unit. Then, the converted optical signal having the wavelength $\lambda 0$ is routed via the second optical line ($\lambda 0$) from the intra-office signal output unit to the intra-output office optical transmission line #1 (see Fig. 19(b)).

Also, another optical signal C ($\lambda 8$) supplied from the optical transmission line between input offices #1 is inputted via the first optical line ($\lambda 1$ to $\lambda 8$) separated from the wavelength branching unit into the routing unit

for λ1 to λ8 (see Fig. 20(a)). The wavelength λ8 of this optical signal C is converted into the wavelength λ1 by the wavelength converter of this routing unit. Then, the converted optical signal having the wavelength λ1 is routed via the second optical line (λ1 to λ8) from the wavelength combining unit to the intra-output office transmission line #1.

Also, another optical signal D (λ17) supplied from the optical transmission line between input offices #1 is inputted via the first optical line (λ17 to λ24) separated from the wavelength branching unit into the routing unit for λ17 to λ24 (see Fig. 21(a)). The wavelength λ17 of this optical signal D is converted into the wavelength λ24 by the wavelength converter of this routing unit. Then, the converted optical signal having the wavelength λ24 is routed via the second optical line (λ17 to λ24) from the wavelength combining unit to the intra-output office optical transmission line #6.

ARRANGEMENT OF SECOND OPTICAL XC DEVICE

Fig. 5 is a diagram for showing an arrangement of an optical line XC device according to an embodiment 2 of the present invention.

Also, Fig. 13 indicates an arrangement of an intra-office signal input unit, an arrangement of a routing

unit, and an arrangement of an intra-office signal output unit. Furthermore, Fig. 9 represents a concrete arrangement of the routing unit in this embodiment 2.

This embodiment 2 has a feature that optical signals are wavelength-multiplexed in the intra-office transmission line, as compared with the embodiment 1 shown in Fig. 4. Other arrangements of this embodiment 2 are the same as those of the embodiment 1.

As shown in this drawing, the intra-office signal input unit is constituted by 64×64 optical switches and wavelength-division demultiplexer, and the routing unit is constituted by 64×64 optical switches and a wavelength converter. In this case, this wavelength converter is equipped with only the optical transmission line between output offices. An output wavelength of this wavelength converter corresponds to a wavelength allocated to each of the respective routing units. Also, the intra-office signal output unit is arranged by 64×64 optical switches, a wavelength converter, and a wavelength-division multiplexer. It should be understood that a concrete structure of an optical switch is similar to that shown in Fig. 22.

In this case, the above-described wavelength branching unit distributes 32 wavelength components to 4

sets of routing units (λ1 to λ8), (λ9 to λ16), (λ17 to λ24), and (λ25 to λ32) in a unit of 8 wavelengths.

In this embodiment 2, the inter-office optical signals entered into the wavelength branching unit are 32 $\times$6=192 channels, and the intra-office optical signals entered into the intra-office signal input unit are 32 $\times$2=64 channels.

The intra-office signal input unit distributes the wavelength-multiplexed optical signals entered from the intra-input office optical transmission line to the respective desirable routing units. Then, the intra-office signal output unit distributes the optical signals which are entered thereinto from the respective routing units to the desirable intra-output station optical transmission line having the desirable wavelengths, respectively.

ARRANGEMENT OF THIRD OPTICAL XC DEVICE

Fig. 6 is a diagram showing an arrangement of an optical XC device according to an embodiment 3.

As indicated in Fig. 6, the optical XC device, according to the embodiment 3, is arranged by an optical branching unit provided every optical transmission line between input offices; "m(m>1)" pieces of routing units subdivided in a unit of "n(n>1)" wavelengths; an optical

combining unit provided every optical transmission line between output offices; an intra-office signal input unit provided with respect to an intra-input office optical transmission line (without wavelength multiplexing); and an intra-office signal output unit with respect to an intra-output office optical transmission line (without wavelength multiplexing).

The optical branching unit has such a function that while maintaining a wavelength-multiplexed optical signal entered from the intra-input office optical transmission line under wavelength multiplexing state, this wavelength-multiplexed optical signal is distributed to "m" pieces of routing units.

The routing unit has such a function that an optical signal within a pre-allocated wavelength range among the wavelength-multiplexed optical signals entered via the optical branching unit, and also an optical signal entered from the intra-office signal input unit are converted into desirable wavelengths, and then, the optical signals having the converted wavelengths are routed to a desirable optical combining unit, or to the intra-office signal output unit.

The optical combining unit has such a function capable of combining the wavelength-multiplexed optical

signals having the different wavelengths which are inputted from the respective routing units.

Furthermore, the intra-office signal input unit has such a function capable of distributing the optical signals entered from the intra-input office optical transmission line to desirable routing units. Then, the intra-office signal output unit has such a function capable of distributing the optical signals entered from the respective routing units to the desirable intra-output office optical transmission line.

Fig. 14 shows structural examples of the respective units provided in the optical XC device according to this embodiment 3. As indicated in this drawing, the intra-office signal input unit is constituted by 64×64 optical switches. The routing unit is arranged by 64×64 optical switches, a wavelength-division demultiplexer, a wavelength-division multiplexer, and wavelength converters. In the wavelength converters, the output wavelengths of the optical signals sent out to the optical transmission line between the output offices correspond to the wavelengths allocated to the respective routing units, and all of the output wavelengths of the optical signals sent out to the intra-output office optical transmission lines are equal to each other. The

wavelength-division demultiplexer is provided with an input port connected to the optical branching unit, and demultiplexes the optical signal within the wavelength range allocated to the respective routing units. The wavelength-division multiplexer is provided with an output port connected to the optical combining unit. The inter-office signal output unit is constructed by 64×64 optical switches.

Fig. 10 is a diagram indicating a more detailed routing operation by this optical XC device.

As indicated in this drawing, in the concrete cross-connect device of this embodiment 3, a total number of wavelengths on the input side is 32, and then, these 32 wavelengths are distributed to 4 sets of routing units in a unit of 8 wavelengths. A ratio of the optical signal channel number derived from the optical transmission line (inter-office) to the optical signal channel number derived from the intra-office transmission line is set to 3:1. As a result, a total channel number of the intra-office optical signals is 32×6=192, whereas a total channel number of the inter-office optical signals is 32 ×2=64.

ARRANGEMENT OF FOURTH OPTICAL XC DEVICE

Fig. 7 is a diagram showing an arrangement of an

optical XC device according to an embodiment 4.

In comparison with the device arrangement of the embodiment 3 shown in Fig. 6, the optical XC device of this embodiment 4 is characterized in that an optical signal is wavelength-multiplexed in an intra-office transmission line. Other arrangements of this optical XC device are similar to those of the above-explained embodiment 3.

As indicated in this drawing, the optical XC device, according to the embodiment 4, is arranged by an optical branching unit provided every optical transmission line between input offices; "m(m>1)" pieces of routing units subdivided in a unit of "n(n>1)" wavelengths; an optical combining unit provided every optical transmission line between output offices; an intra-office signal input unit provided with respect to an intra-input office optical transmission line (with wavelength multiplexing); and an inter-office signal output unit with respect to an intra-output office optical transmission line (with wavelength multiplexing).

The optical branching unit has such a function that while maintaining a wavelength-multiplexed optical signal entered from the intra-input office optical transmission line under wavelength multiplexing state, this wavelength-multiplexed optical signal is distributed to

"m" pieces of routing units.

The routing unit has such a function that an optical signal within a pre-allocated wavelength range among the wavelength-multiplexed optical signals entered via the optical branching unit, and also an optical signal entered from the intra-office signal input unit is converted into desirable wavelengths, and then, the optical signals having the converted wavelengths are routed to a desirable optical combining unit, or to the intra-office signal output unit.

The optical combining unit has such a function capable of combining the wavelength-multiplexed optical signals having the different wavelengths which are inputted from the respective routing units.

Furthermore, the intra-office signal input unit has such a function capable of distributing the wavelength-multiplexed optical signals entered from the intra-input office optical transmission line to desirable routing units. Then, the intra-office signal output unit has such a function capable of distributing the optical signals entered from the respective routing units to the desirable wavelength and to the desirable intra-output station optical transmission line.

Fig. 15 shows structural examples of the respective

units provided in the optical XC device according to this embodiment 4.

That is to say, the intra-office signal input unit is constituted by 64×64 optical switches and a wavelength-division demultiplexer. The routing unit is arranged by 64×64 optical switches, a wavelength-division demultiplexer, a wavelength-division multiplexer, and wavelength converters. The wavelength converters are provided only on the side of the optical transmission line between the output offices, and the output wavelengths of the optical signals correspond to the wavelengths allocated to the respective routing units. The wavelength-division demultiplexer is provided with an input port connected to the optical branching unit, and demultiplexes the optical signal within the wavelength range allocated to the respective routing units. The wavelength-division multiplexer is provided with an output port connected to the optical combining unit.

Furthermore, the intra-office signal output unit is arranged by 64×64 optical switches, a wavelength converter, and a wavelength-division multiplexer.

To avoid degradation of a transfer characteristic of an optical signal, a regenerator (arranged by opto-electric converter and electric-optical converter) may be

provided at either an input of an optical switch or an output thereof in the above-explained intra-office signal input unit and intra-office signal output unit.

Fig. 11 is a diagram indicating a more detailed routing operation by this optical XC device of the embodiment 4.

As indicated in this drawing, in the concrete cross-connect device of this embodiment 4, a total number of wavelengths on the input side is 32, and then, these 32 wavelengths are distributed to 4 sets of routing units in a unit of 8 wavelengths. A ratio of the optical signal channel number derived from the optical transmission line (inter-office) to the optical signal channel number derived from the inter-office transmission line is set to 3:1. As a result, a total channel number of the inter-office optical signals is $32 \times 6 = 192$, whereas a total channel number of the intra-office optical signals is $32 \times 2 = 64$.

It should be understood in this specification that the routing unit, the intra-office signal input unit, the intra-office signal output unit, and the optical switch are not limited to the above-explained structural examples.

As previously explained in detail, in accordance with

the present invention, a single sub-network is constituted by the wavelength converting type routing unit in the unit of extension. Then, the wavelength converting type routing units are successively added in response to an increase in the wavelength numbers (namely, a plurality of sub-networks are additionally provided) so as to constitute a large-scaled optical XC device and an optical network. As a consequence, while maintaining the transfer characteristic, these optical XC device and optical network have the expanding characteristic with respect to the wavelength number. Furthermore, it can prevent the large-scaled system. This may contribute to an improvement in the performance of the optical transfer system with employment of this arrangement.

WHAT IS CLAIMED IS:

1. An optical path cross-connect device for accommodating a plurality of inter-office transmission line (with wavelength multiplexing) and a plurality of intra-office transmission lines (without wavelength multiplexing), comprising:

a wavelength branching unit provided with each of said inter-office transmission line, for demultiplexing wavelength-multiplexed optical signals entered from said inter-office transmission line to a first optical path group;

an intra-office signal input unit provided with each of said intra-office transmission lines, for repeating a wavelength-non-multiplexed signal entered from said intra-office transmission line to said first optical path group;

"m" pieces of routing units for inputting thereinto an optical signal outputted from any one of said wavelength branching unit or said intra-office signal input unit via said first optical path group, and for converting said optical input signal into a predetermined wavelength to thereby output the wavelength-converted optical signal to a second optical path group, said "m (symbol "m" being an integer and also being larger than 1)" pieces of routing

units being subdivided in a unit of at least "n (symbol "n" being an integer and also being larger than 1)" wavelengths;

a wavelength combining unit for accommodating thereinto said second optical path group and for selectively wavelength-multiplexing said optical signal; and

an intra-office signal output unit for accommodating thereinto said second optical path group and for selectively repeating said optical signal.

2. An optical path cross-connect device as claimed in claim 1 wherein:

the optical signal transferred to said intra-office transmission line is wavelength-multiplexed; and both said intra-office signal input unit and said intra-office signal output unit repeat the wavelength-multiplexed optical signal.

3. An optical path cross-connect device for accommodating a plurality of inter-office transmission lines (with wavelength multiplexing) and a plurality of intra-office transmission lines (without wavelength multiplexing), comprising:

an optical branching unit provided with each of said inter-office transmission line, for branching a

wavelength-multiplexed optical signal entered from said intra-office transmission line into "m (symbol "m" being an integer and also being larger than 1)" pieces of first optical path groups, while maintaining the wavelength-multiplexed state;

an intra-office signal input unit provided with each of said intra-office transmission lines, for repeating a wavelength-non-multiplexed optical signal entered from said intra-office optical transmission line;

"m" pieces of routing units for routing an optical signal within a pre-allocated wavelength range from optical signals outputted from said optical branching unit and said intra-office signal input unit to an inter-office signal output unit, and for converting said optical signal within said pre-allocated wavelength range into a desirable wavelength to route the wavelength-converted optical signal to a second optical path group, said "m (symbol "m" being an integer and also being larger than 1)" pieces of routing units being subdivided in a unit of at least "n (symbol "n" being an integer and also being larger than 1)" wavelengths;

a wavelength combining unit for accommodating thereinto said second optical path group and for selectively wavelength-multiplexing said optical signal;

and

an intra-office signal output unit for accommodating thereinto said second optical path group and for selectively repeating said optical signal.

4. An optical path cross-connect device as claimed in claim 3 wherein:

the optical signal transferred to said inter-office transmission line is wavelength-multiplexed; and both said intra-office signal input unit and said intra-office signal output unit repeat the wavelength-multiplexed optical signal.

5. An optical path cross-connect device as claimed in claim 1 wherein:

said intra-office signal input unit is constituted by an optical space switch; said routing unit is arranged by an optical space switch and a wavelength converter; and said intra-office signal output unit is arranged by an optical space switch.

6. An optical path cross-connect device as claimed in claim 2 wherein:

said intra-office signal input unit is arranged by a wavelength-division demultiplexer, and an optical space switch; said routing unit is constituted by an optical space switch and a wavelength converter; and said

intra-office signal output unit is arranged by an optical space switch, a wavelength converter, and a wavelength-division multiplexer.

7. An optical path cross-connect device as claimed in claim 3 wherein:

said intra-office signal input unit is constituted by an optical space switch; said routing unit is arranged by a wavelength-division demultiplexer, an optical space switch, a wavelength converter and a wavelength-division multiplexer; and said intra-office signal output unit is arranged by an optical space switch.

8. An optical path cross-connect device as claimed in claim 4 wherein:

said intra-office signal input unit is arranged by a wavelength-division demultiplexer, and an optical space switch; said routing unit is constituted by a wavelength-division demultiplexer, an optical space switch, a wavelength converter and a wavelength-division multiplexer; and said intra-office signal output unit is arranged by an optical space switch, a wavelength converter, and a wavelength-division multiplexer.

9. An optical path cross-connect device as claimed in any one of the preceding claims 5 to 8 wherein:

in said intra-office signal input unit and said

inter-office signal output unit, a regenerator constructed of both an opto-electric converter and an electric-optical converter is employed at any one of an input of said optical space switch and an output thereof.

10. An optical network wherein:

a plurality of the optical path cross-connect devices as claimed in any one of the preceding claims 1 to 4 are employed so as to constitute said optical network.

ABSTRACT OF THE DISCLOSURE

To realize an optical path cross-connect technique having a high expanding characteristic with respect to an increase in a total number of wavelengths while maintaining a better transfer characteristic, an optical path cross-connect device is provided with a wavelength separating means every inter-office transmission line. Also, an intra-office signal input means is provided so as to demultiplex a wavelength-multiplexed optical signal entered from the inter-office transmission line to a first optical path group, and repeat a wavelength-non-multiplexed optical signal to the first optical path group. Then, this optical path cross-connect device is provided with "m" pieces of routing means for inputting thereinto an optical signal via this first optical path group, and for converting this optical input signal into a predetermined wavelength to thereby output the wavelength-converted optical signal to a second optical path group. The "m (symbol "m" being an integer and also being larger than 1)" pieces of routing means are subdivided in a unit of at least "n (symbol "n" being an integer and also being larger than 1)" wavelengths. Furthermore, there are provided a wavelength combining means for selectively wavelength-multiplexing the optical

signal through the second optical path group, and an intra-office signal output means for selectively repeating the optical signal at a post stage of the above-explained routing means.

FIG. 1

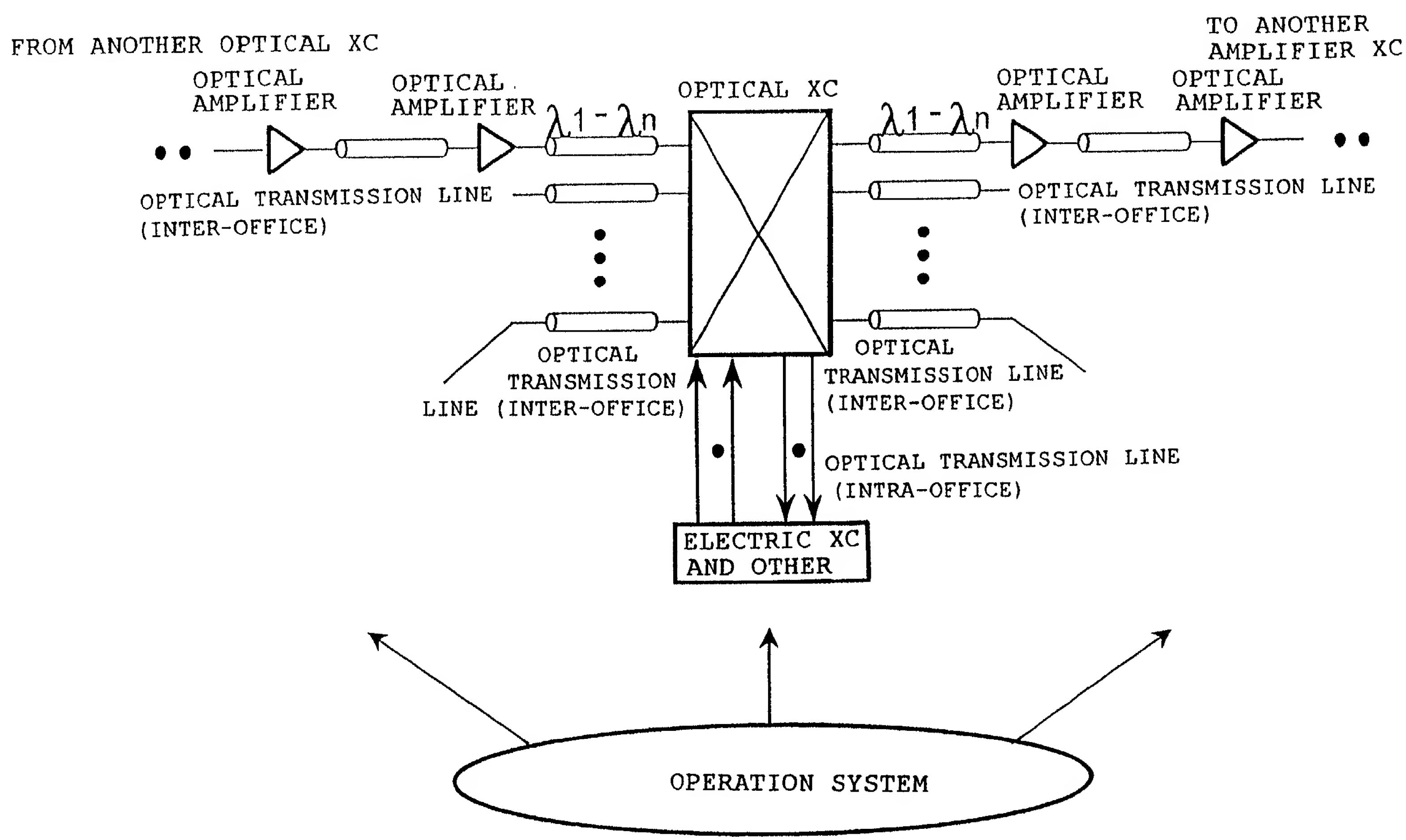
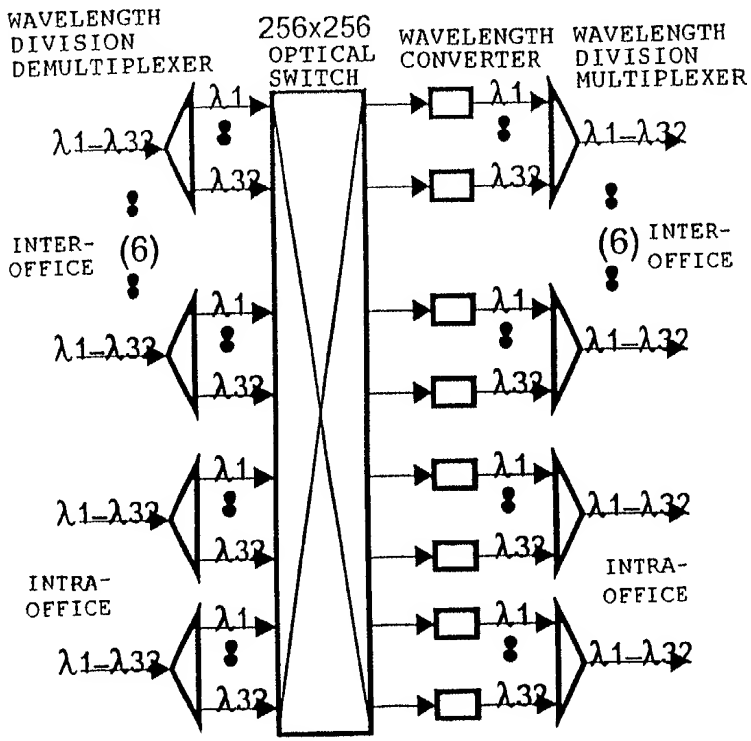
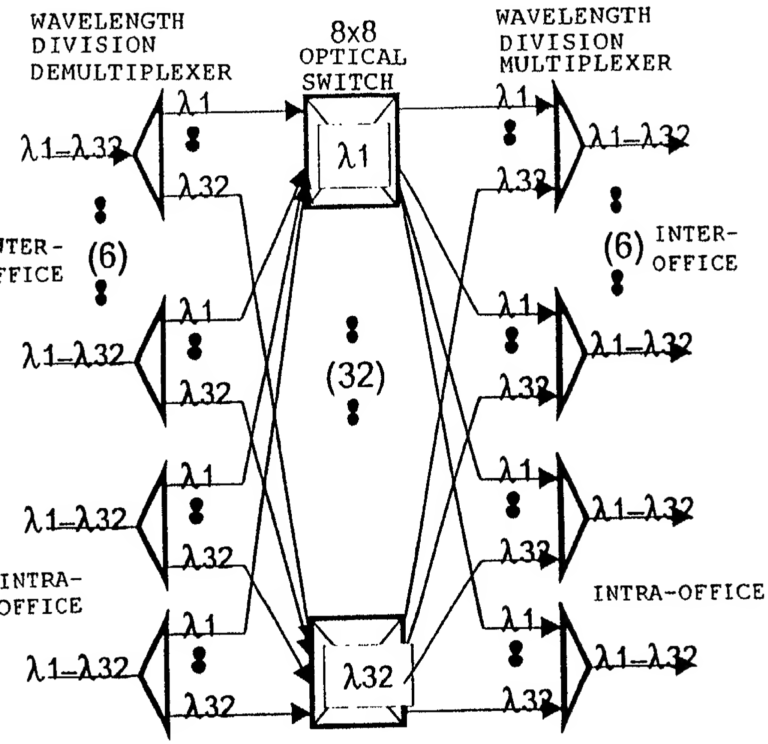

FROM ANOTHER OPTICAL XC
OPTICAL AMPLIFIER
OPTICAL AMPLIFIER
λ1 - λn
OPTICAL XC
λ1 - λn
OPTICAL AMPLIFIER
OPTICAL AMPLIFIER
TO ANOTHER AMPLIFIER XC
OPTICAL TRANSMISSION LINE (INTER-OFFICE)
OPTICAL TRANSMISSION LINE (INTER-OFFICE)
OPTICAL TRANSMISSION LINE (INTER-OFFICE)
OPTICAL TRANSMISSION LINE (INTER-OFFICE)
OPTICAL TRANSMISSION LINE (INTRA-OFFICE)
ELECTRIC XC AND OTHER
OPERATION SYSTEM

FIG. 2



(a) WAVELENGTH CONVERTING TYPE



(b) WAVELENGTH FIXING TYPE

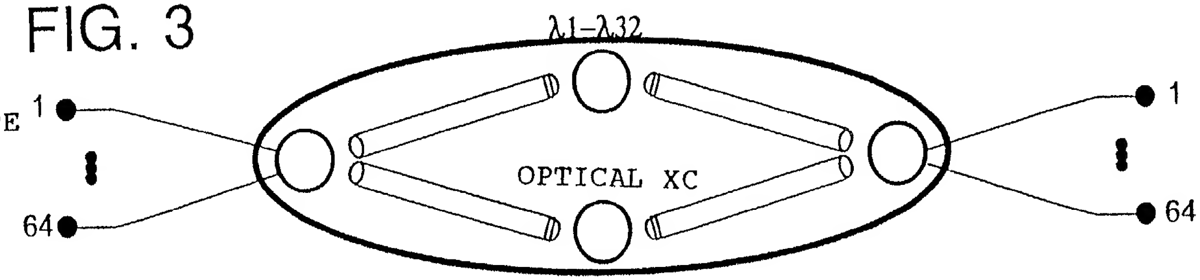
※ INTER-OFFICE LINK NUMBER: 6

※ INTRA-OFFICE LINK NUMBER: 2

※ WAVELENGTH MULTIPLEXED NUMBER: 32

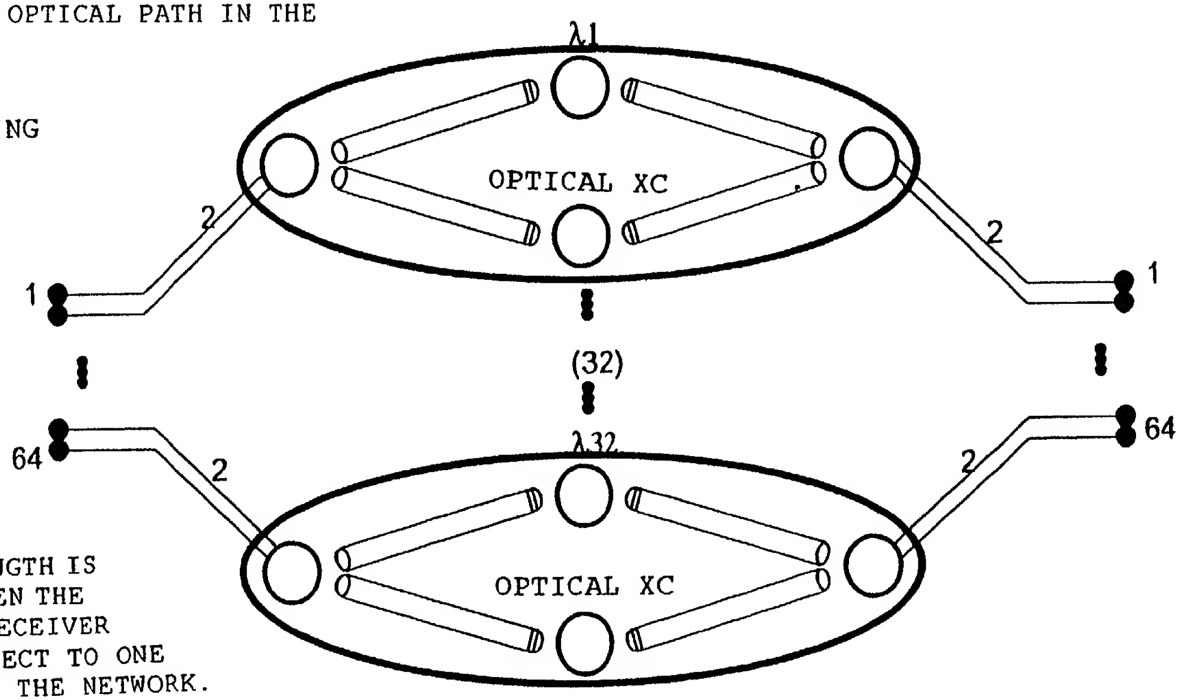
FIG. 3

(a) WAVELENGTH CONVERTING TYPE OPTICAL PATH NETWORK



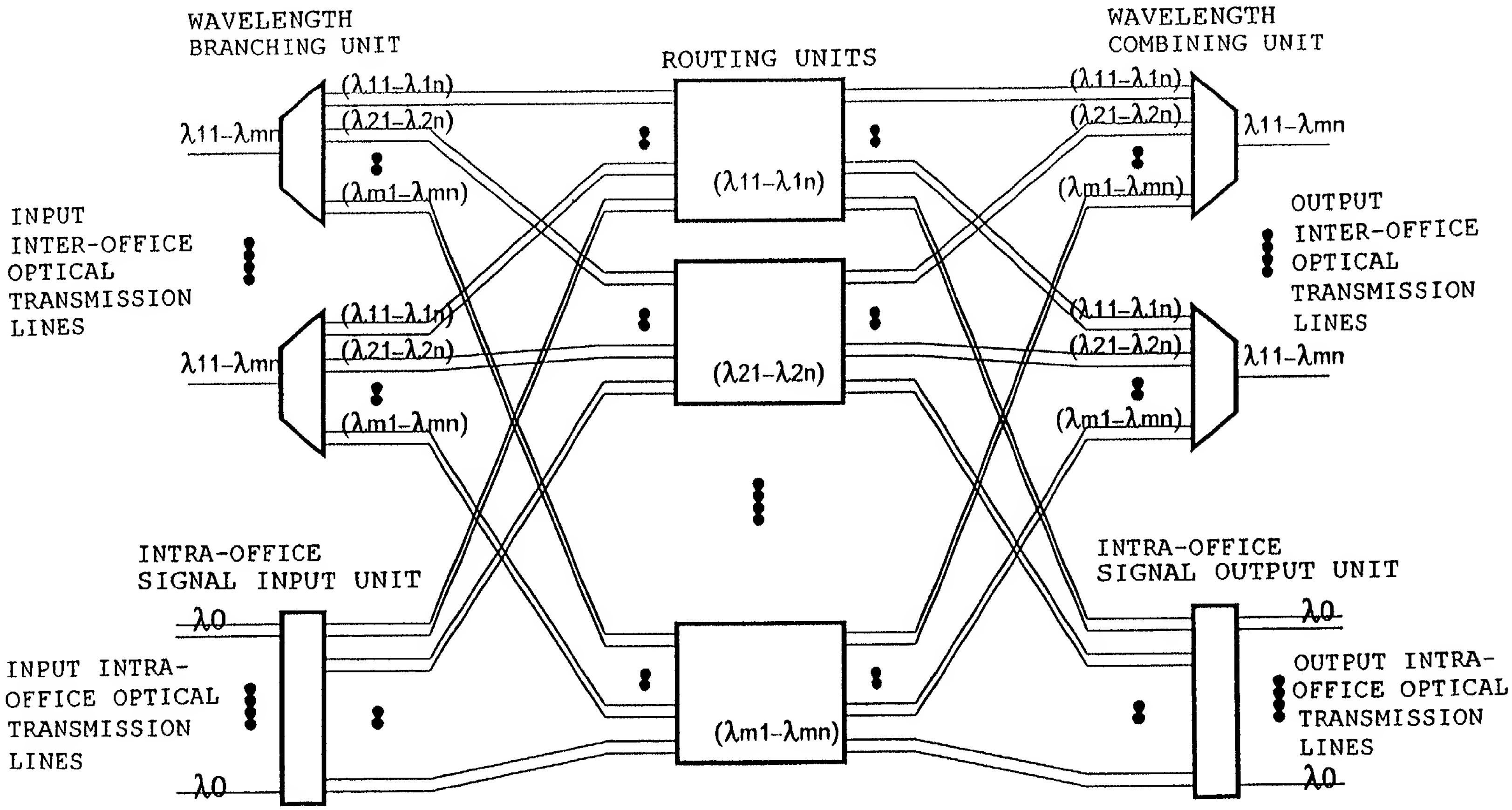
※ THE WAVELENGTHS ARE ALLOCATED IN THE LINK-BY-LINK BASIS BETWEEN THE SENDER AND RECEIVER NODES WITH RESPECT TO ONE OPTICAL PATH IN THE NETWORK.

(b) WAVELENGTH FIXING TYPE OPTICAL PATH NETWORK



※ A SINGLE WAVELENGTH IS ALLOCATED BETWEEN THE SENDER AND THE RECEIVER NODES WITH RESPECT TO ONE OPTICAL PATH IN THE NETWORK.

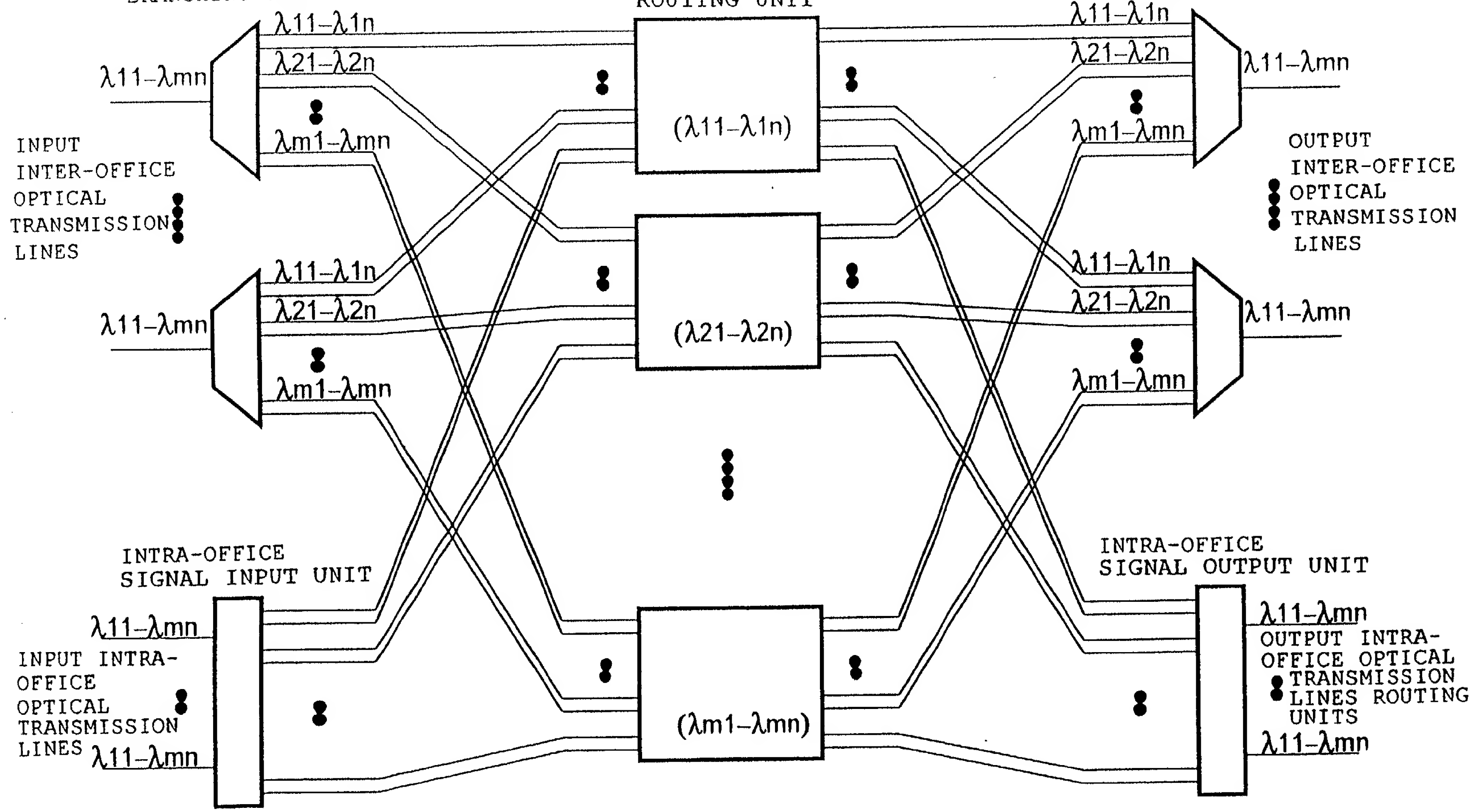
FIG. 4



※ SUBDIVIDED INTO "M" PIECES OF ROUTING UNITS IN UNIT OF "N" WAVELENGTHS

※ PROVIDED WITH WAVELENGTH CONVERTER EACH OF THE RESPECTIVE

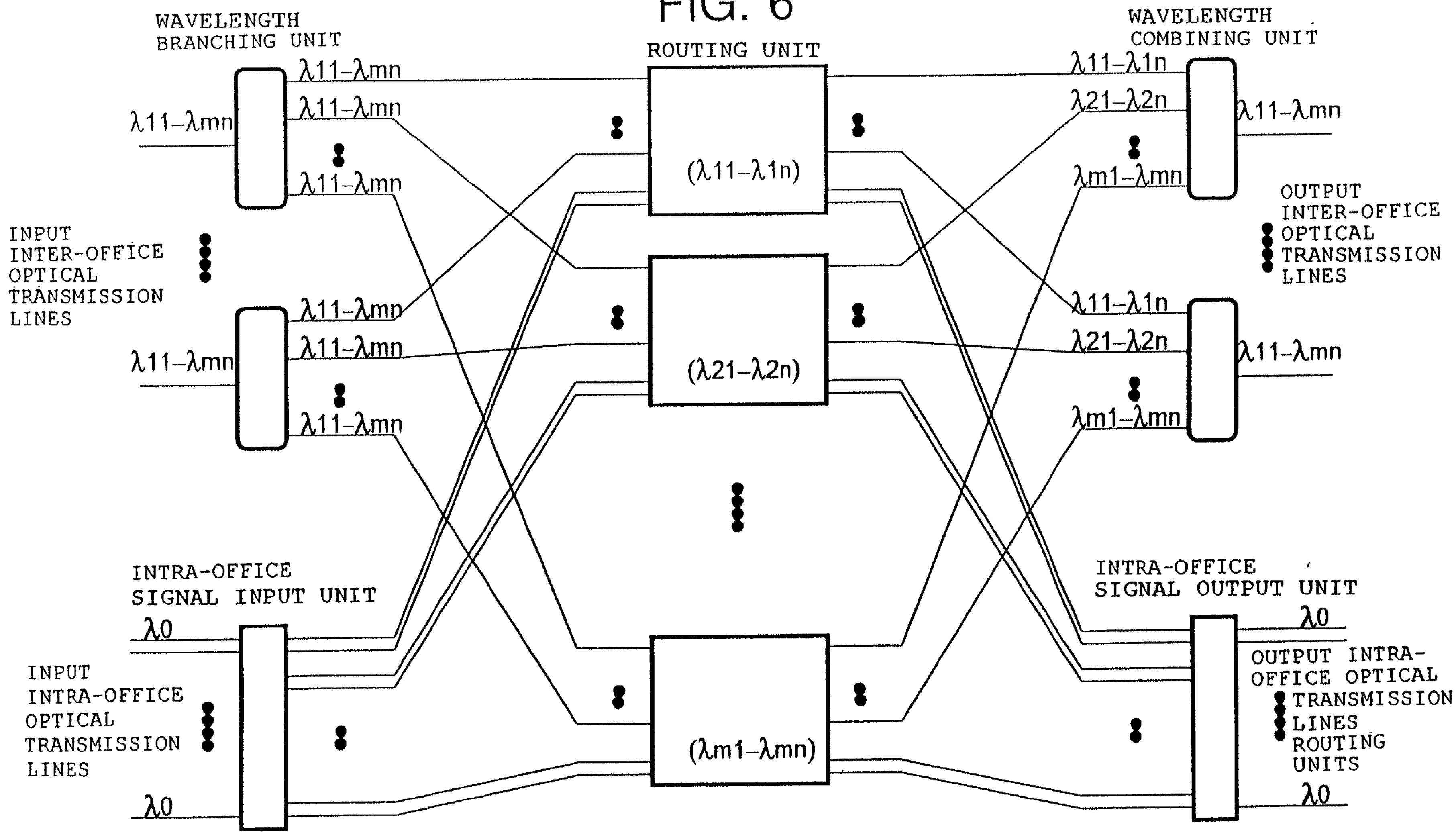
FIG. 5



※ SUBDIVIDED INTO "M" PIECES OF ROUTING UNITS IN UNIT OF "N" WAVELENGTHS

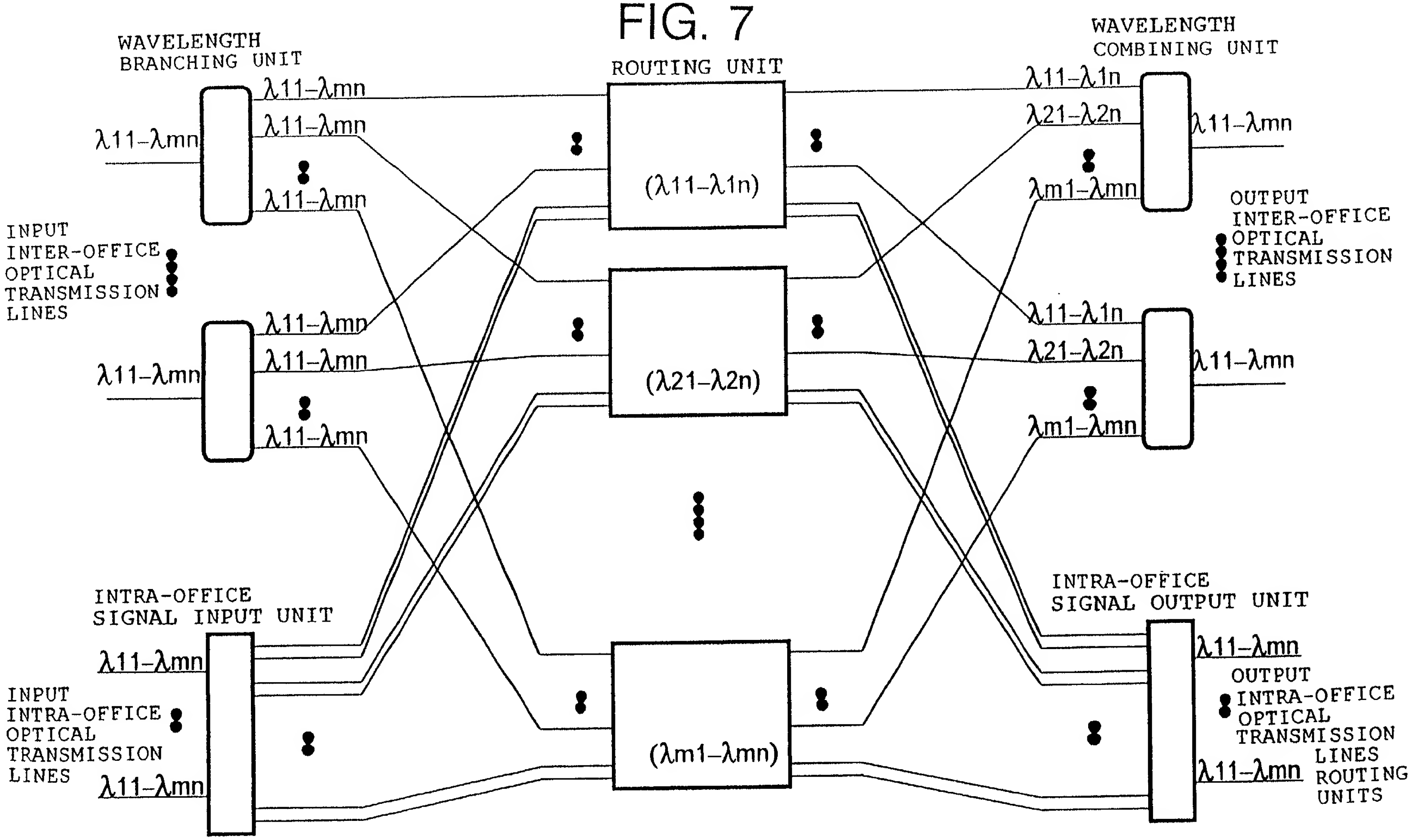
※ PROVIDED WITH WAVELENGTH CONVERTER EACH OF THE RESPECTIVE

FIG. 6



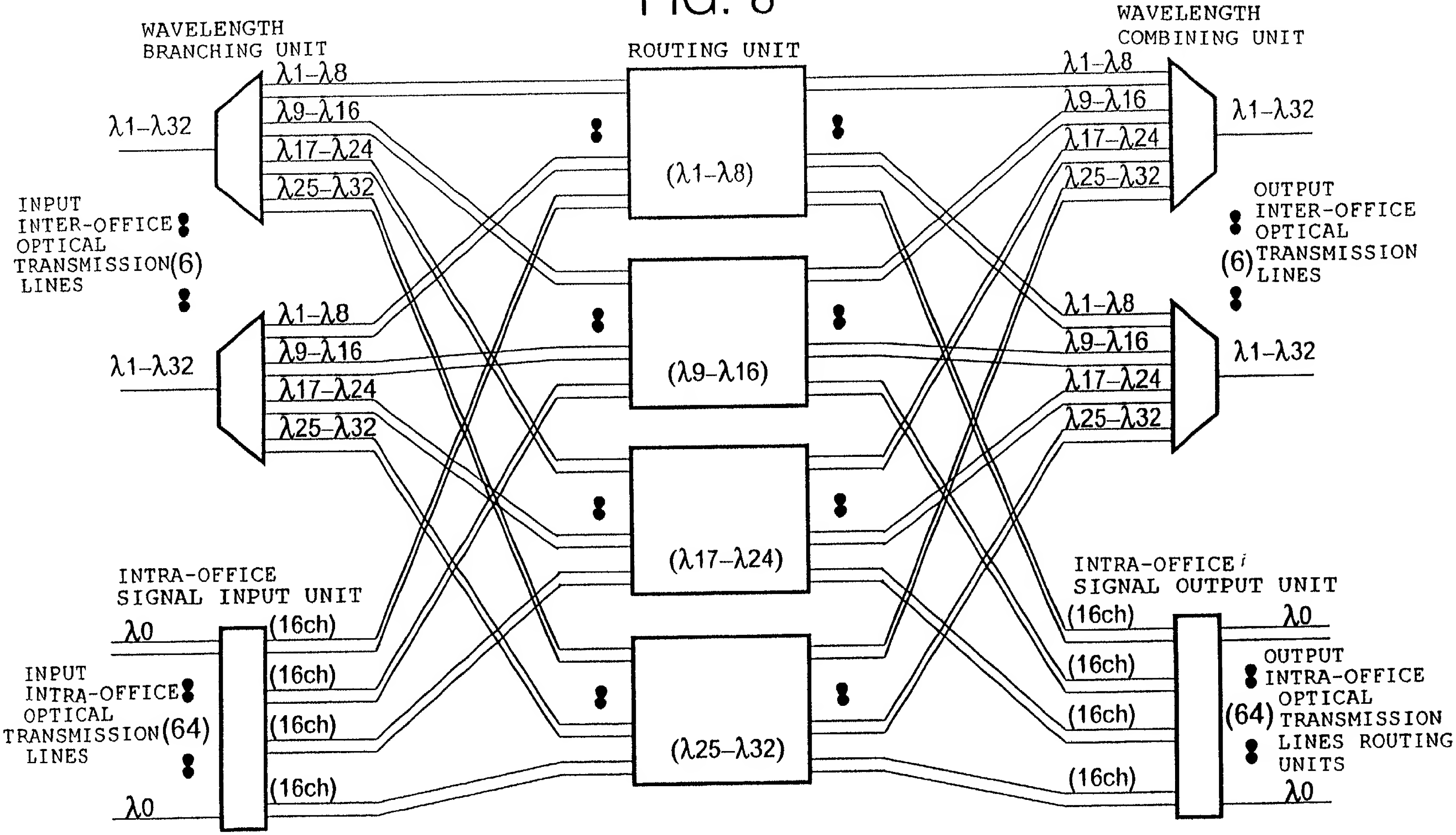
※ SUBDIVIDED INTO "M" PIECES OF ROUTING UNITS IN UNIT OF "N" WAVELENGTHS
※ PROVIDED WITH WAVELENGTH CONVERTER EACH OF THE RESPECTIVE

FIG. 7



※ SUBDIVIDED INTO "M" PIECES OF ROUTING UNITS IN UNIT OF "N" WAVELENGTHS
※ PROVIDED WITH WAVELENGTH CONVERTER EACH OF THE RESPECTIVE

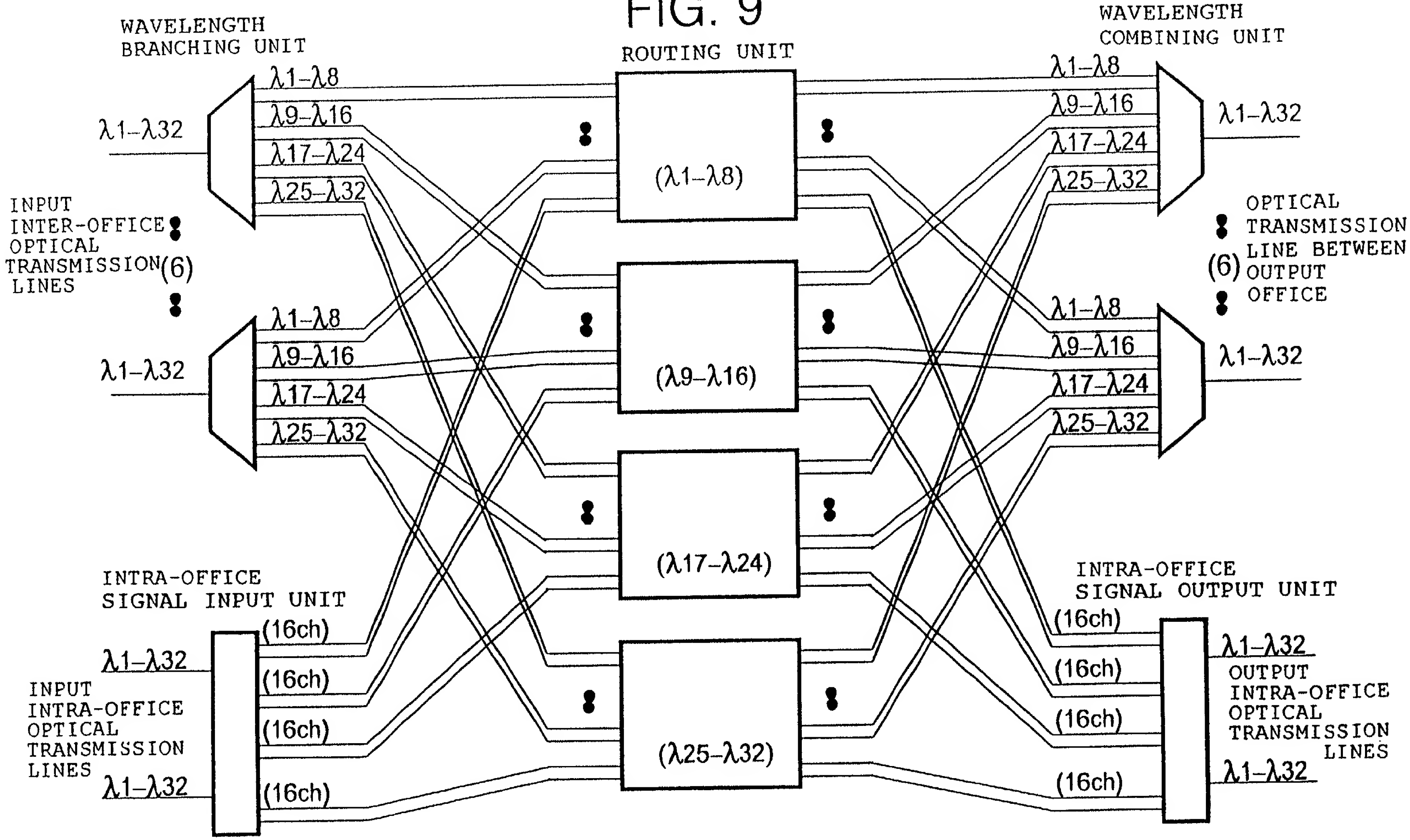
FIG. 8



※ SUBDIVIDED BY 4 PIECES OF ROUTING UNITS IN UNIT OF 8 WAVELENGTHS (WAVELENGTH NUMBER : 32)

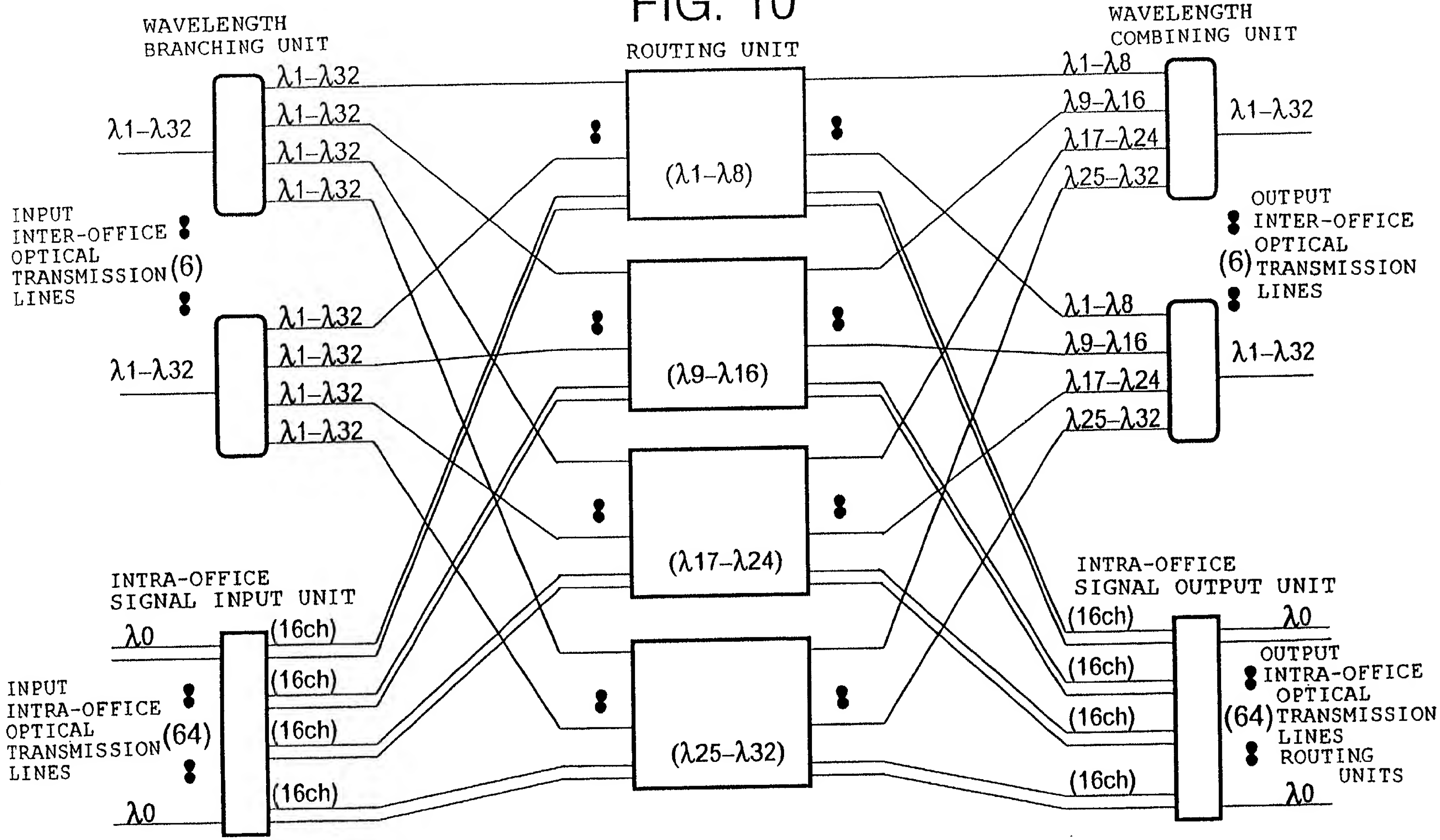
※ INTER-OFFICE OPTICAL SIGNAL CHANNEL NUMBER : 192
INTRA-OFFICE OPTICAL SIGNAL CHANNEL NUMBER : 64

FIG. 9



※ SUBDIVIDED BY 4 PIECES OF ROUTING UNITS IN UNIT OF 8 WAVELENGTHS
(WAVELENGTH NUMBER : 32)
※ INTER-OFFICE OPTICAL SIGNAL CHANNEL NUMBER : 192
INTRA-OFFICE OPTICAL SIGNAL CHANNEL NUMBER : 64

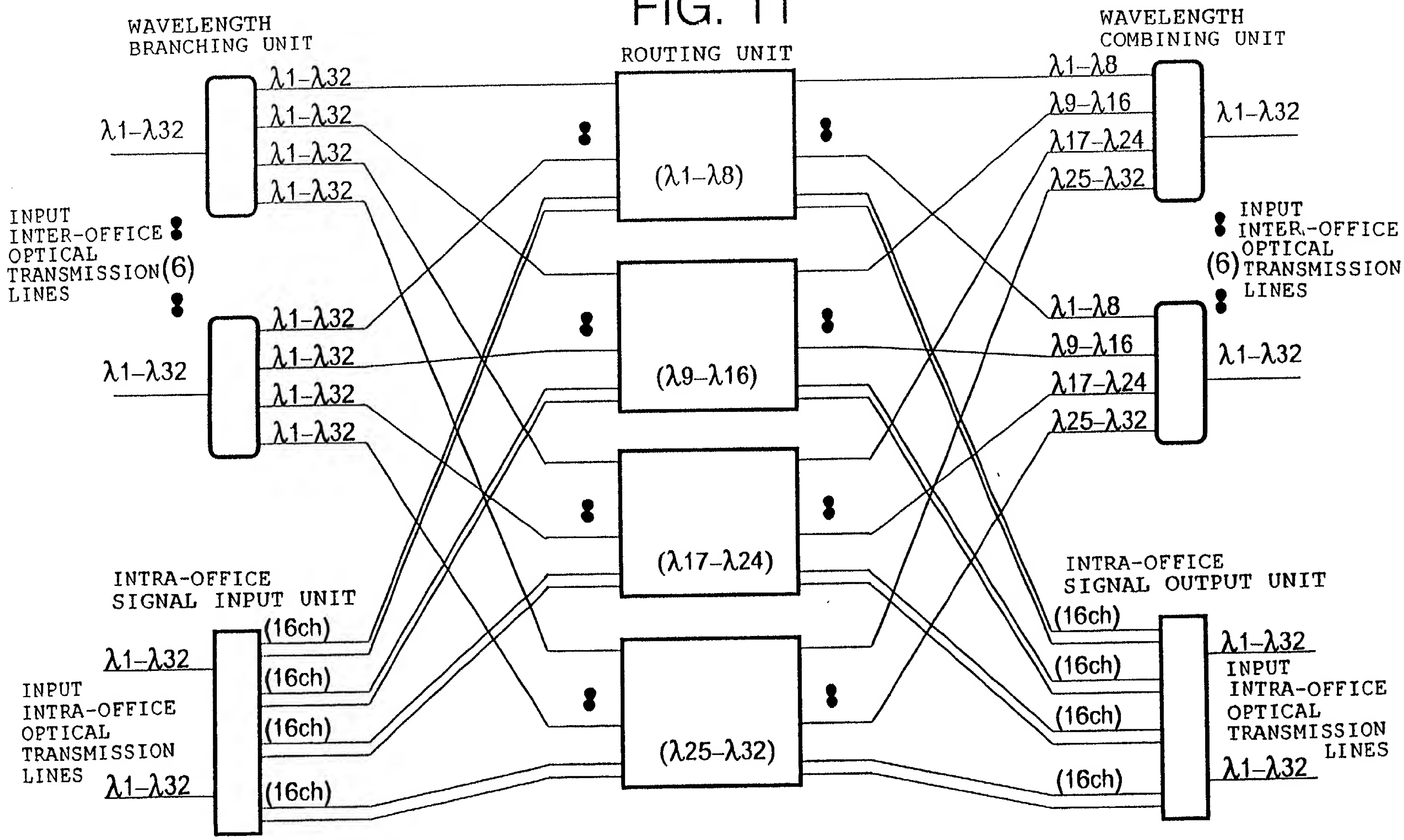
FIG. 10



※ SUBDIVIDED BY 4 PIECES OF ROUTING UNITS IN UNIT OF 8 WAVELENGTHS (WAVELENGTH NUMBER : 32)

※ INTER-OFFICE OPTICAL SIGNAL CHANNEL NUMBER : 192
INTRA-OFFICE OPTICAL SIGNAL CHANNEL NUMBER : 64

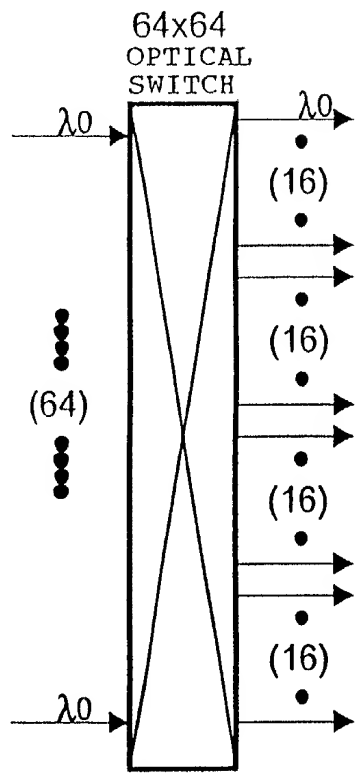
FIG. 11



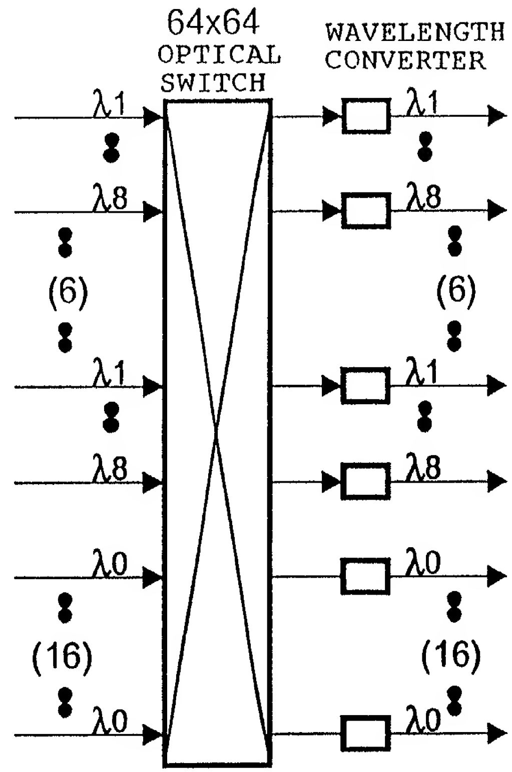
※ SUBDIVIDED BY 4 PIECES OF ROUTING UNITS IN UNIT OF 8 WAVELENGTHS (WAVELENGTH NUMBER : 32)

※ INTER-OFFICE OPTICAL SIGNAL CHANNEL NUMBER : 192
INTRA-OFFICE OPTICAL SIGNAL CHANNEL NUMBER : 64

FIG. 12

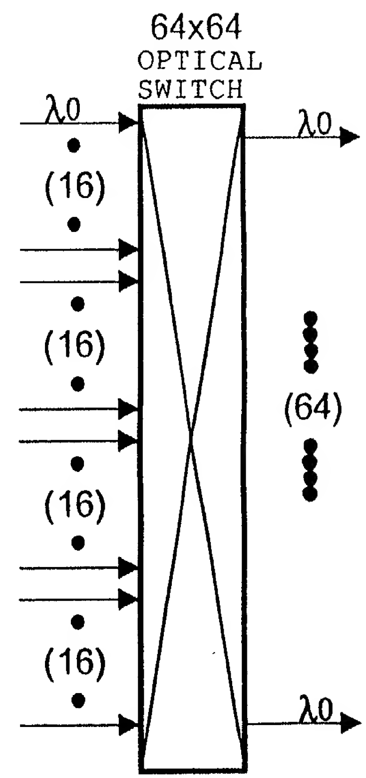


(a) INTRA-OFFICE SIGNAL INPUT UNIT



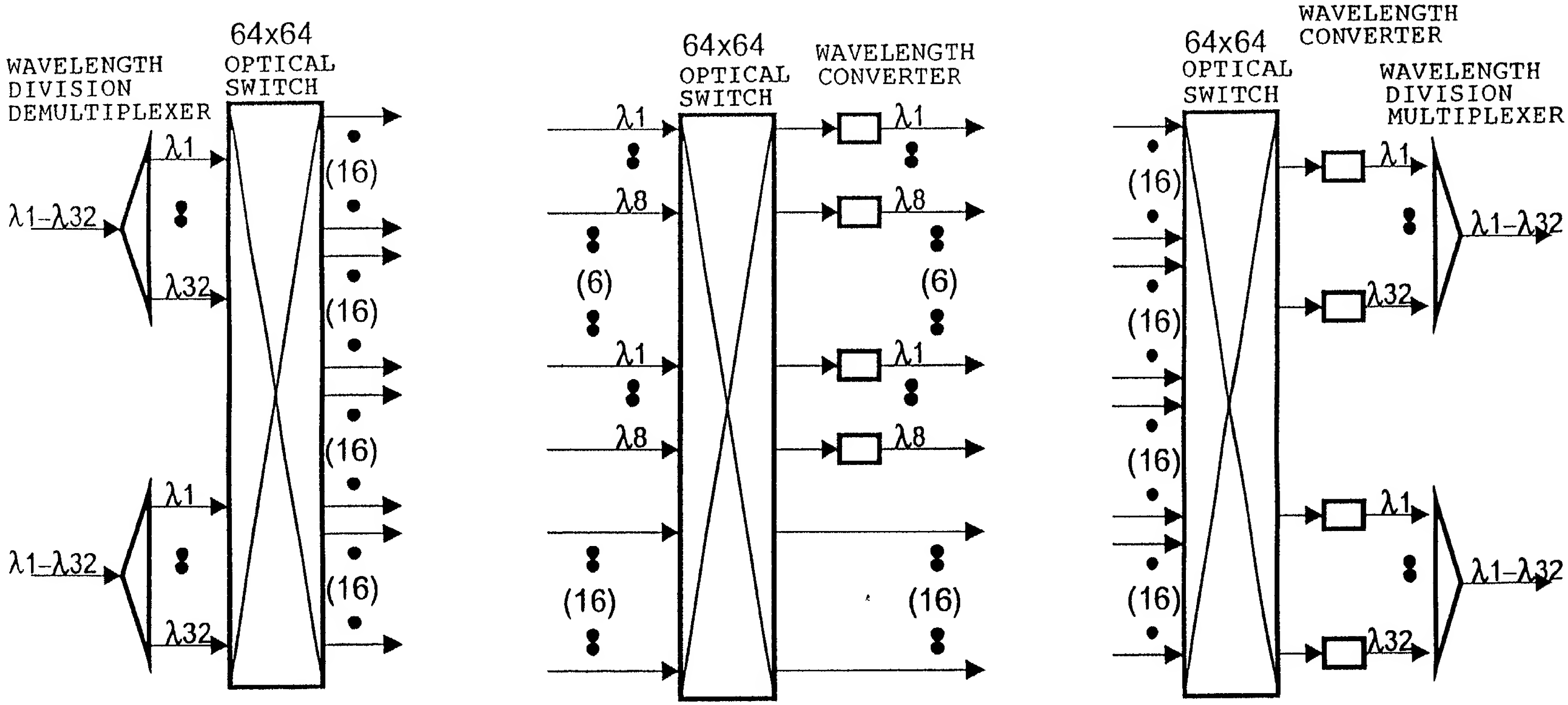
※ROUTING UNIT FOR λ1 TO λ8

(b) ROUTING UNIT



(c) INTRA-OFFICE SIGNAL OUTPUT UNIT

FIG. 13



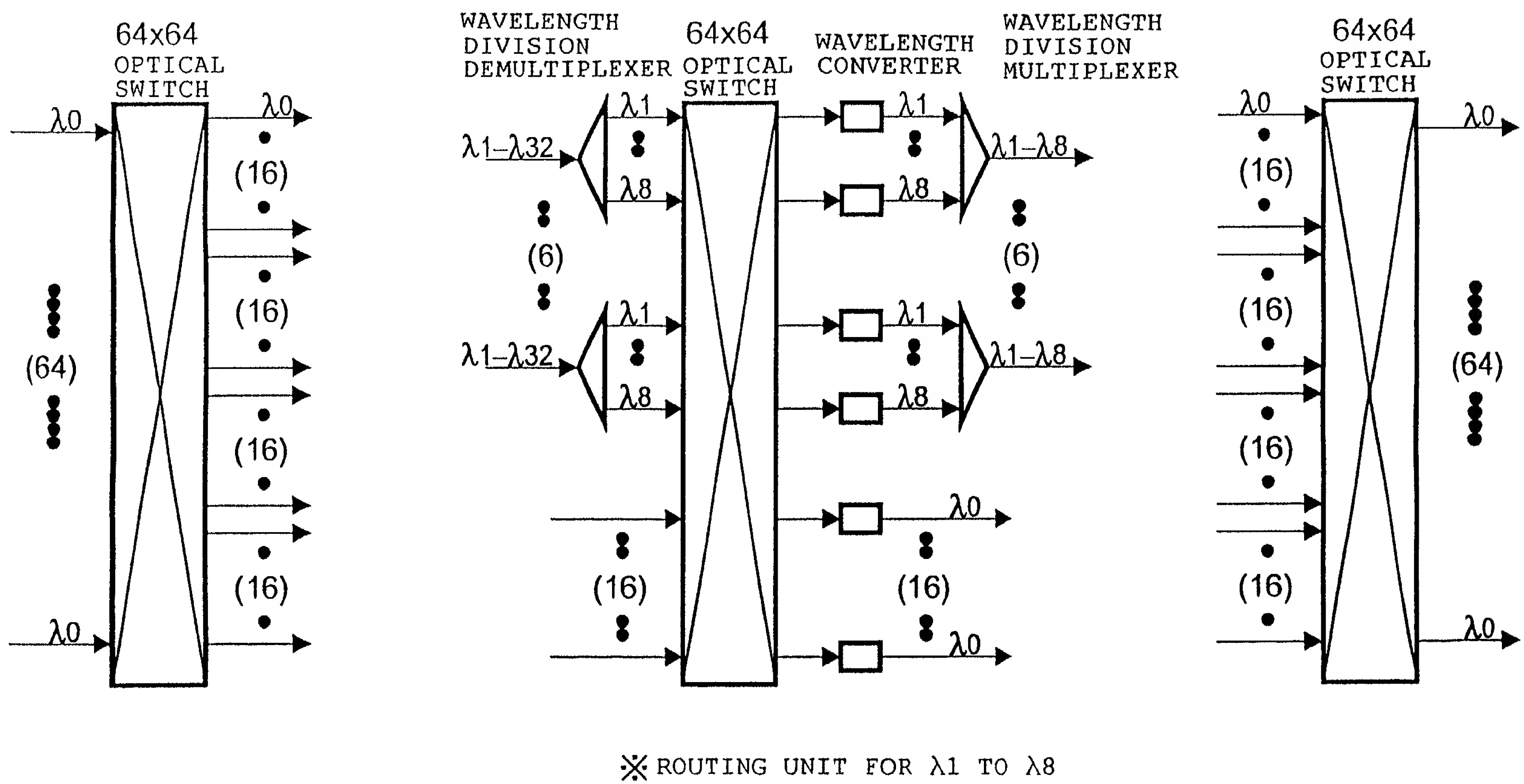
※ROUTING UNIT FOR λ1 TO λ8

(a) INTRA-OFFICE SIGNAL INPUT UNIT

(b) ROUTING UNIT

(c) INTRA-OFFICE SIGNAL OUTPUT UNIT

FIG. 14

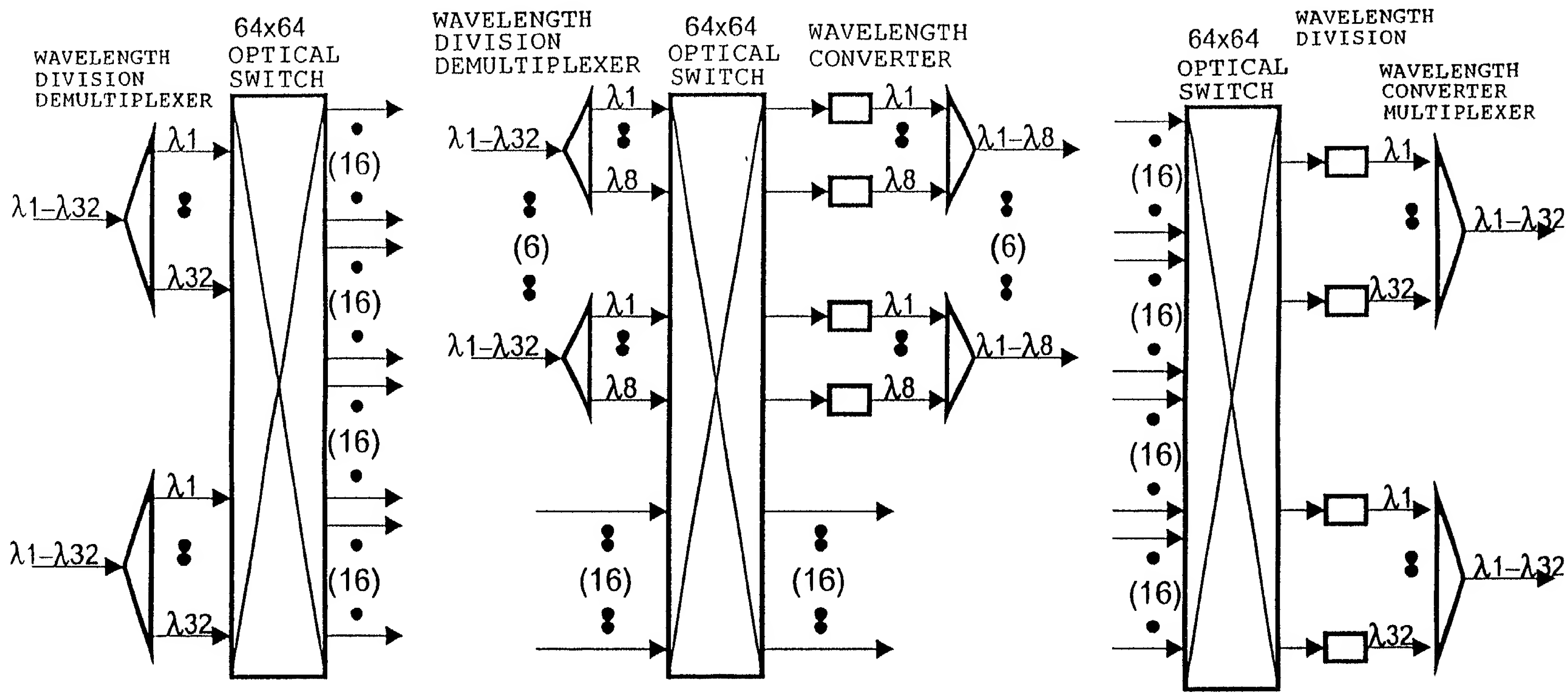


(a) INTRA-OFFICE SIGNAL INPUT UNIT

(b) ROUTING UNIT

(c) INTRA-OFFICE SIGNAL OUTPUT UNIT

FIG. 15



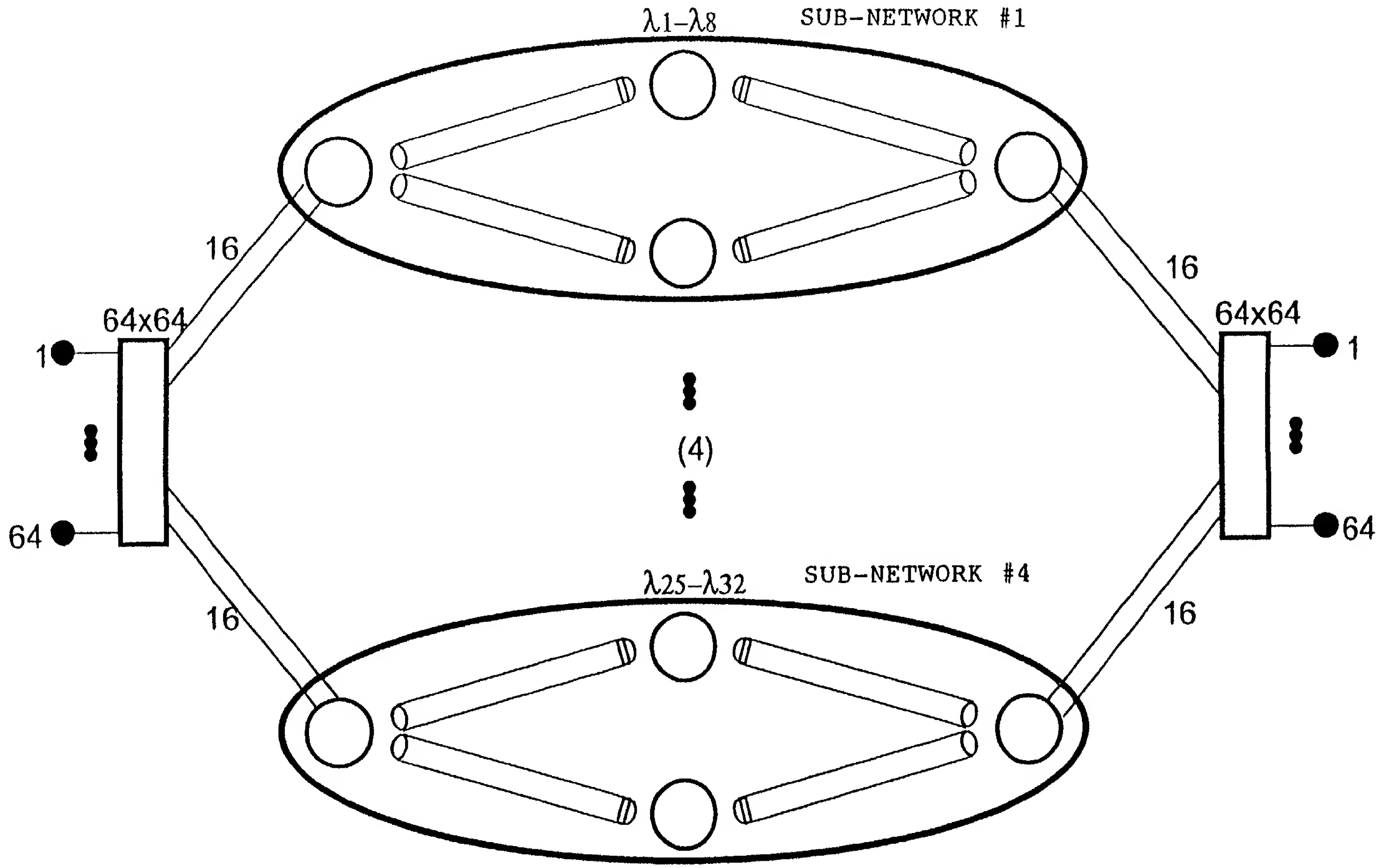
※ ROUTING UNIT FOR λ1 TO λ8

(a) INTRA-OFFICE SIGNAL INPUT UNIT

(b) ROUTING UNIT

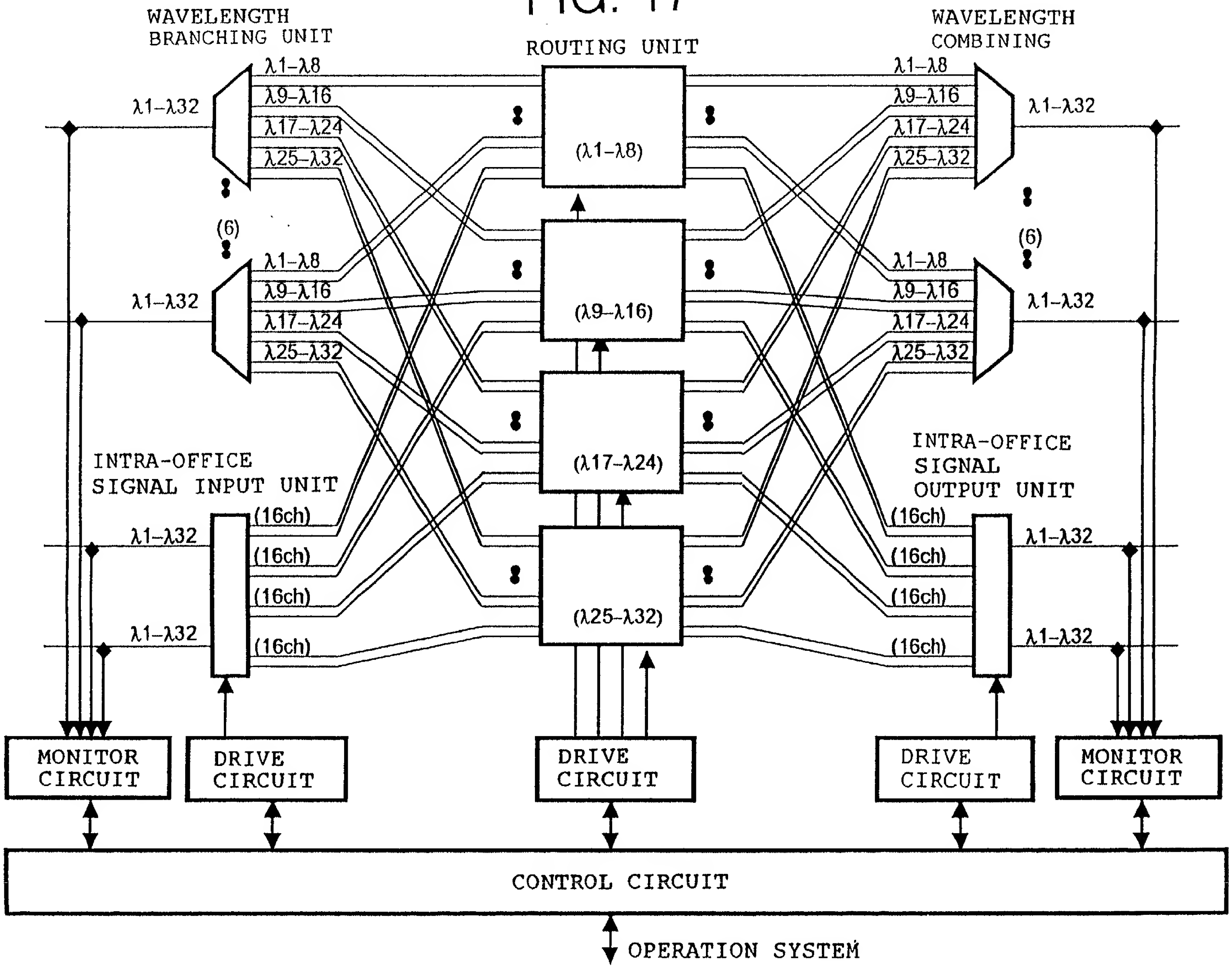
(c) INTRA-OFFICE SIGNAL OUTPUT UNIT

FIG. 16



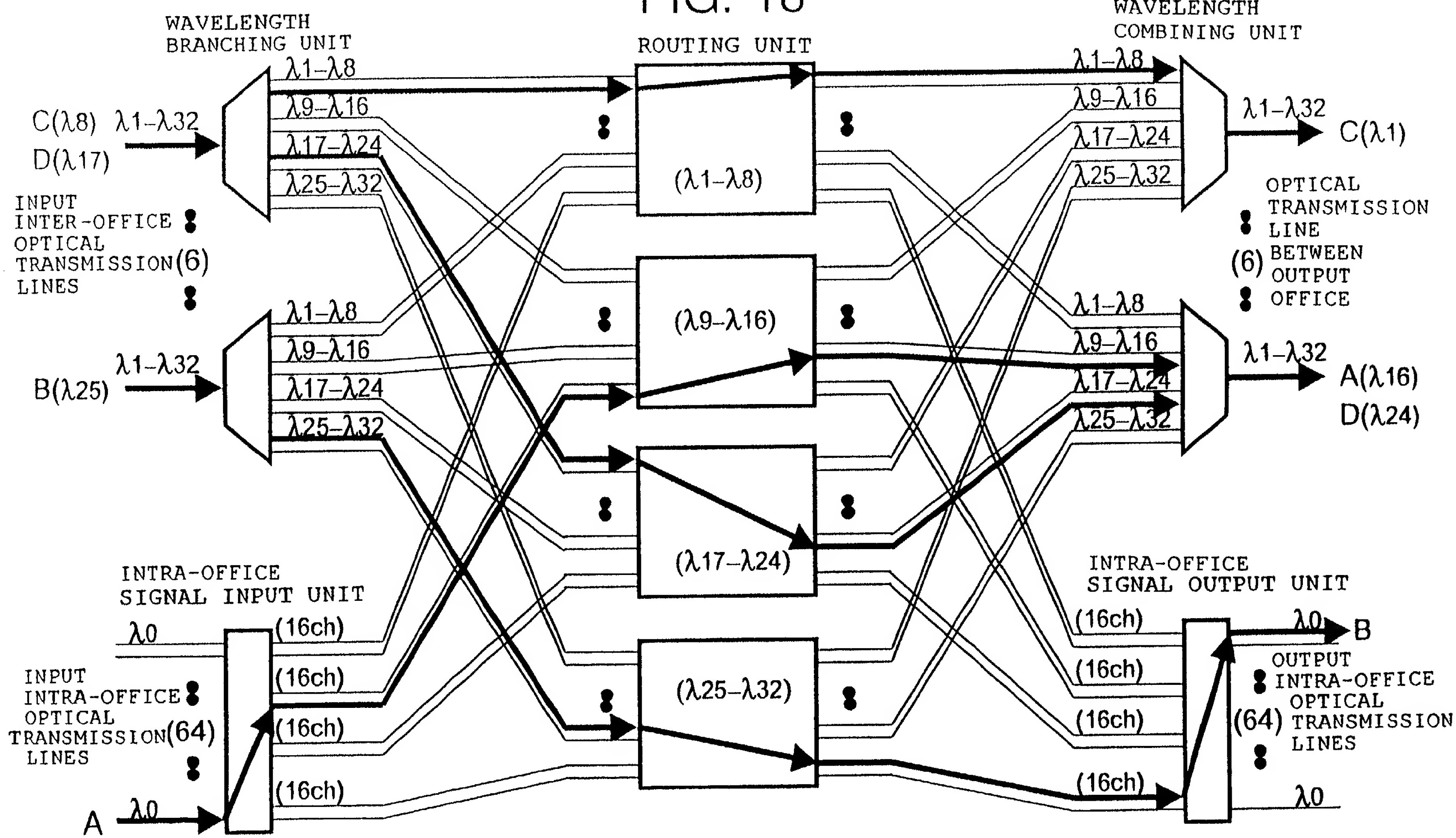
※ THE WAVELENGTHS ARE ALLOCATED IN THE LINK-BY-LINK BASIS IN THE SELECTED SUB-NETWORK BETWEEN THE SENDER AND THE RECEIVER NODES WITH RESPECT TO THE OPTICAL PATH IN THE NETWORK

FIG. 17



WAVELENGTH BRANCHING UNIT
ROUTING UNIT
WAVELENGTH COMBINING
λ1–λ32
λ1–λ8
λ9–λ16
λ17–λ24
λ25–λ32
(6)
(λ1–λ8)
(λ9–λ16)
(λ17–λ24)
(λ25–λ32)
INTRA-OFFICE SIGNAL INPUT UNIT
INTRA-OFFICE SIGNAL OUTPUT UNIT
(16ch)
MONITOR CIRCUIT
DRIVE CIRCUIT
CONTROL CIRCUIT
OPERATION SYSTEM

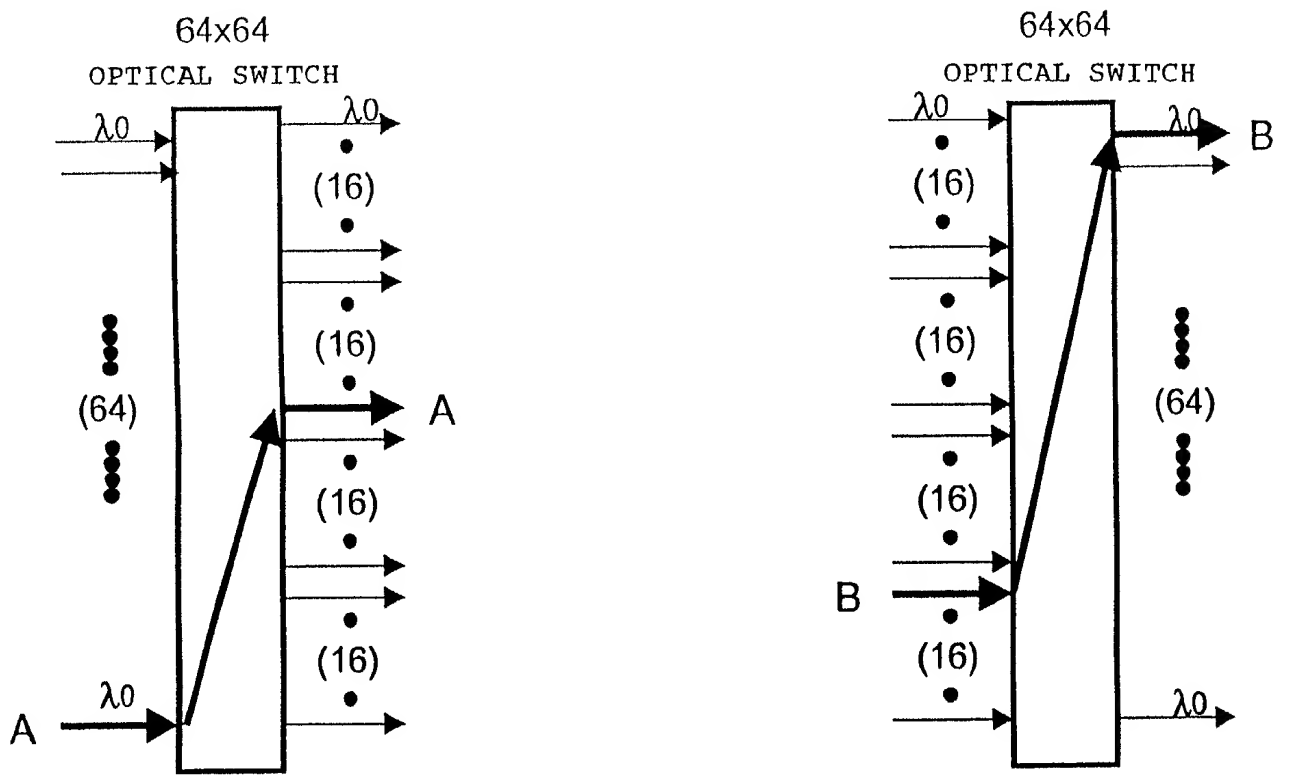
FIG. 18



※ SUBDIVIDED BY 4 PIECES OF ROUTING UNITS IN UNIT OF 8 WAVELENGTHS
(WAVELENGTH NUMBER : 32)

※ INTER-OFFICE OPTICAL SIGNAL CHANNEL NUMBER : 192
INTRA-OFFICE OPTICAL SIGNAL CHANNEL NUMBER : 64

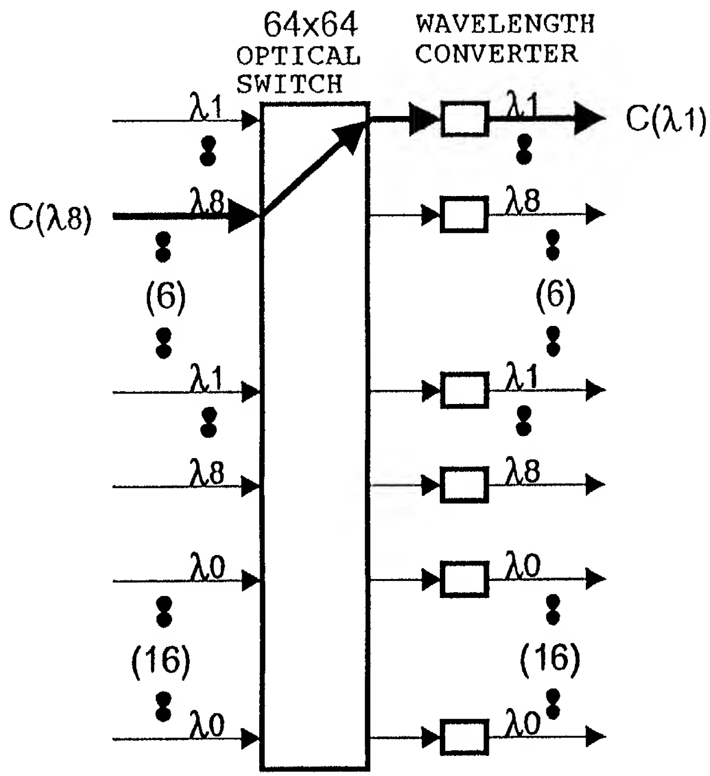
FIG. 19



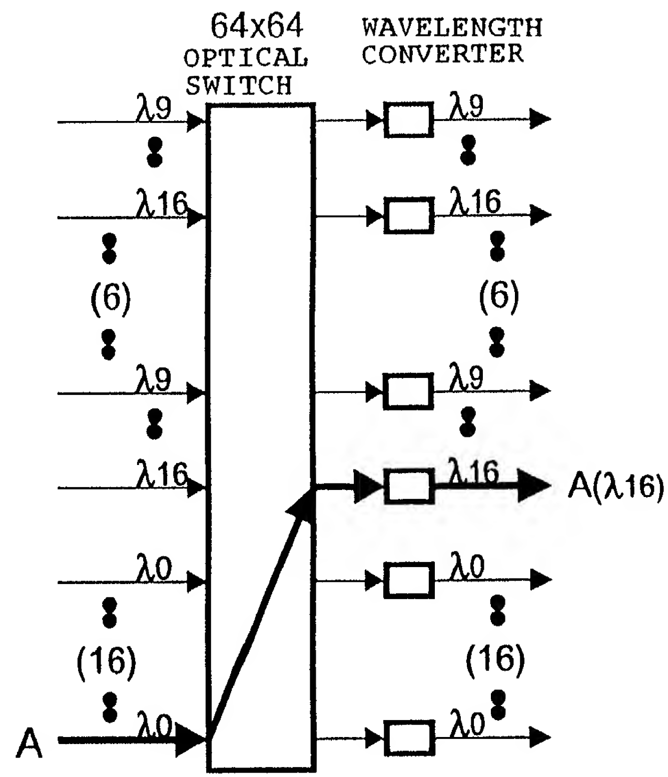
(a) INTRA-OFFICE SIGNAL INPUT UNIT

(b) INTRA-OFFICE SIGNAL OUTPUT UNIT

FIG. 20

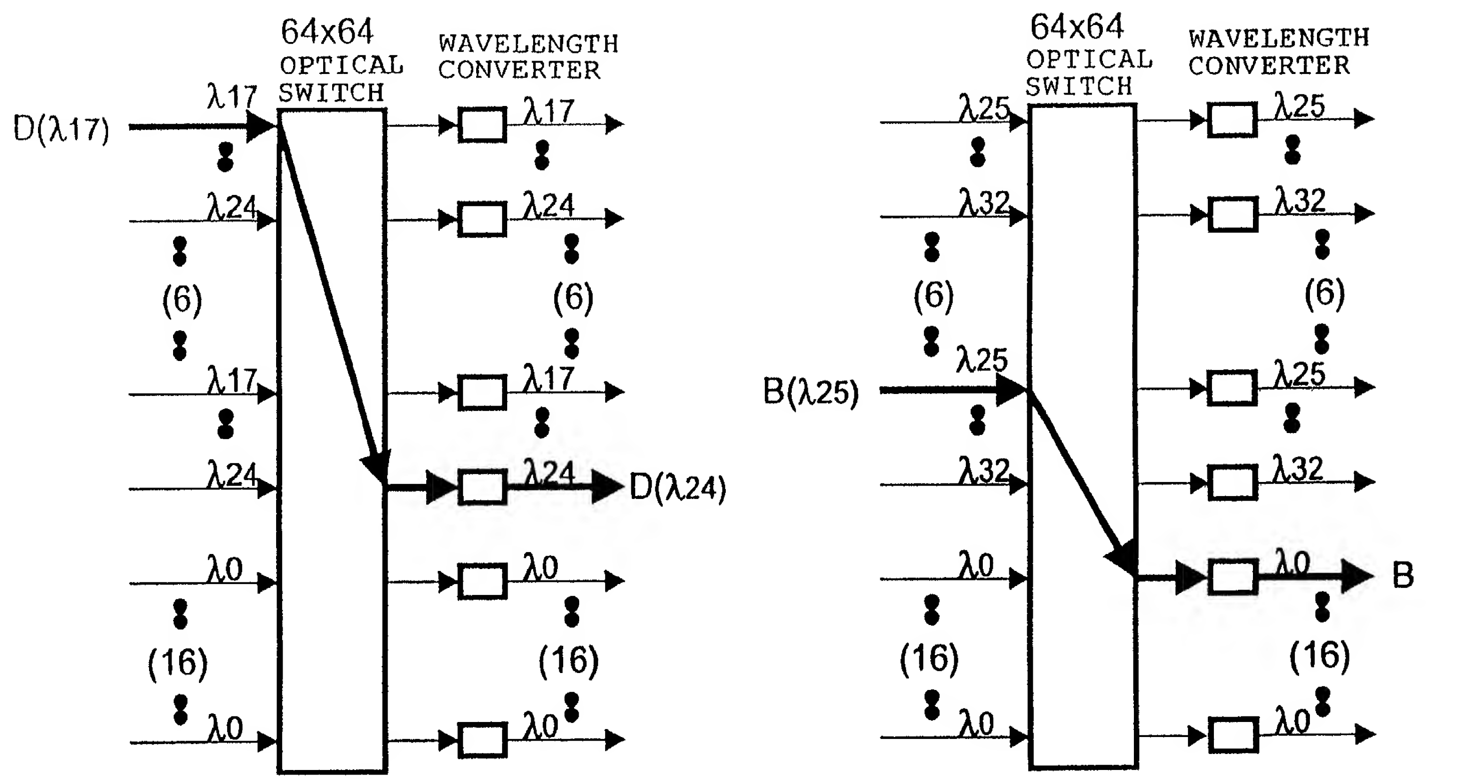


(a) ROUTING UNIT FOR λ1 TO λ8



(b) ROUTING UNIT FOR λ9 TO λ16

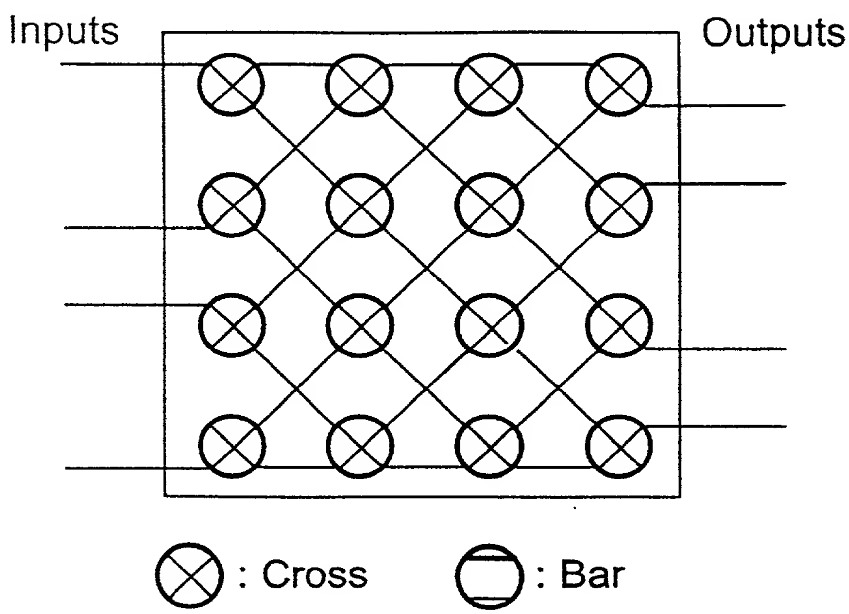
FIG. 21



(a) ROUTING UNIT FOR λ17 TO λ24

(b) ROUTING UNIT FOR λ25 TO λ32

FIG. 22



PTO/SB/106 (8-96)
Approved for use through 9/30/98. OMB 0651-0032
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that:

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

____

____

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

OPTICAL PATH CROSSCONNECT SYSTEM

WITH HIGH EXPANDING CHARACTERISTIC

上記発明の明細書（下記の欄でx印がついていない場合は、本書に添付）は、

the specification of which is attached hereto unless the following box is checked:

☐ __月__日に提出され、米国出願番号または特許協定条約国際出願番号を__________とし、
（該当する場合）__________ に訂正されました。

☐ was filed on ________________
as United States Application Number or
PCT International Application Number
__________ and was amended on
__________ (if applicable).

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第３７編第１条５６項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

Japanese Language Declaration
(日本語宣言書)

私は、米国法典第35編119条(a)-(d)項又は365条(b)項に基き下記の、米国以外の国の少なくとも一ヵ国を指定している特許協力条約365(a)項に基ずく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

I hereby claim foreign priority under Title 35, United States Code, Section 119 (a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)
外国での先行出願

(Number) (番号)	(Country) (国名)	(Day/Month/Year Filed) (出願年月日)	Priority Not Claimed 優先権主張なし
10-368805	Japan	25/12/1998	☐
			☐

私は、第35編米国法典119条(e)項に基いて下記の米国特許出願規定に記載された権利をここに主張いたします。

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.) (出願番号)	(Filing Date) (出願日)	(Application No.) (出願番号)	(Filing Date) (出願日)

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Japanese Language Declaration
(日本語宣言書)

委任状：　私は下記の発明者として、本出願に関する一切の手続きを米特許商標局に対して遂行する弁理士または代理人として、下記の者を指名いたします。（弁護士、または代理人の氏名及び登録番号を明記のこと）

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